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THE PROGRESS OF SCIENCE

"FORWARD-SCATTER" PROPAGATION

WIND TUNNELS AND AEROPLANE DESIGN
A. E. Knowler
M.Sc., Ph.D.
C. M. Britland, *D.Ae.*

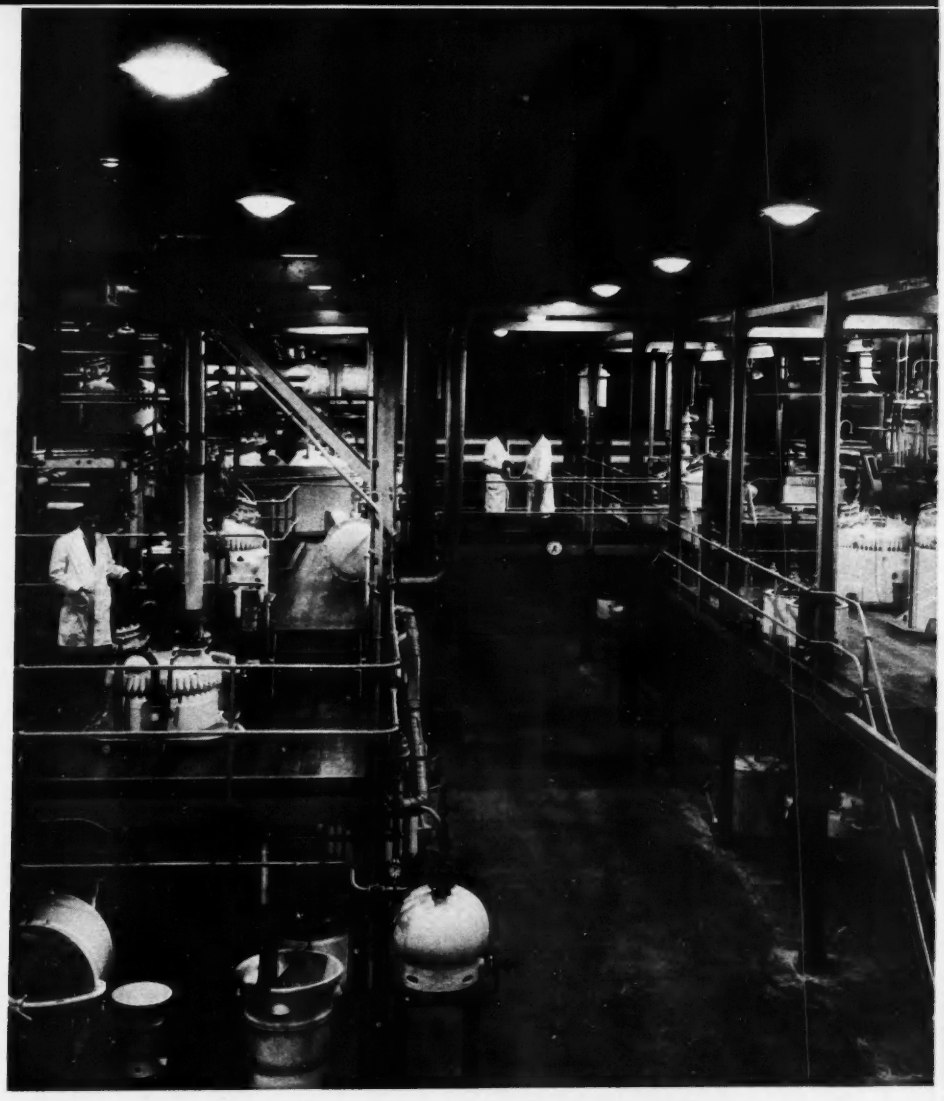
DETERGENTS AND HOW THEY WORK
N. Pilpel,
B.Sc., Ph.D.

JOHN DIEBOLD
Maurice Goldsmith

ELECTRICITY FROM THE ATOM
J. J. Polling
B.Sc.

RATS AND MICE
R. A. Davis
M.Sc., D.I.C., A.R.C.S.

THE NEW SYNTHESIS OF CORTISONE
John Wm. Albans
B.Sc., F.R.I.C.



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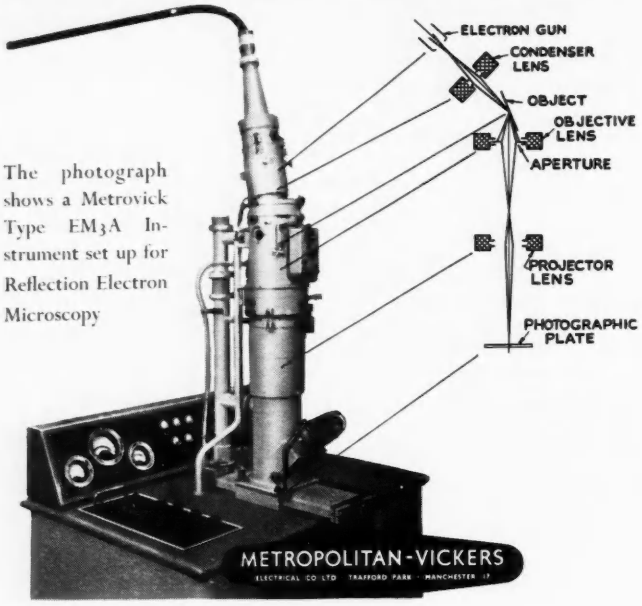

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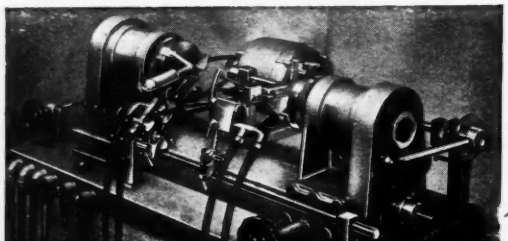

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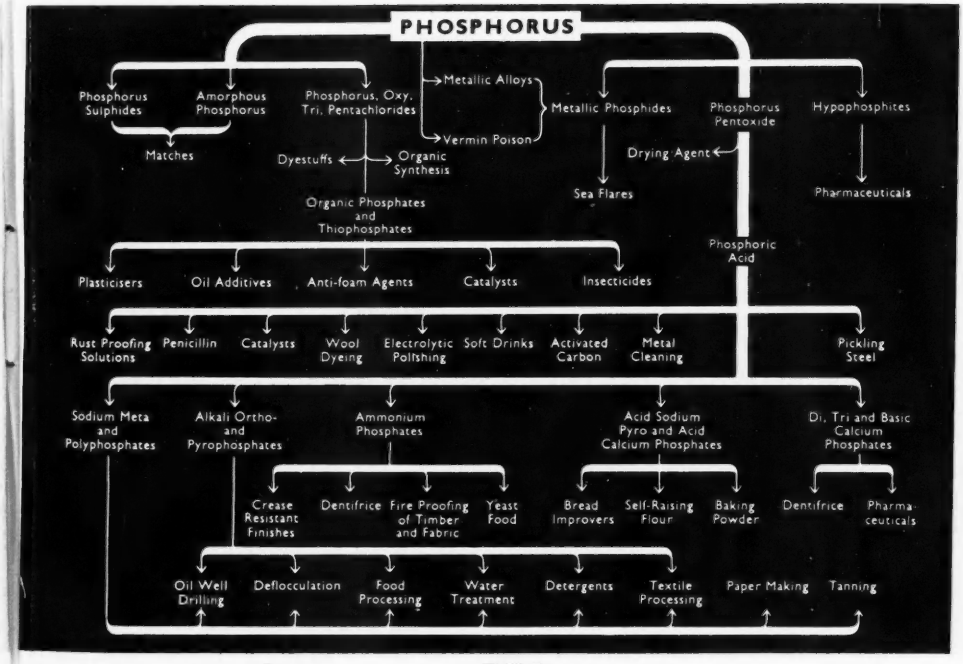

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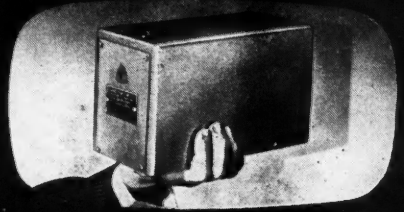

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THE PROGRESS OF SCIENCE

BENJAMIN FRANKLIN (1706–1790): A COMPREHENSIVE GENIUS

The 250th anniversary of the birth of Benjamin Franklin was celebrated by special lectures in London and Manchester. In London there was, too, another kind of celebration, when Sir Winston Churchill was presented with a medal struck in Franklin's honour. This ceremony fittingly took place in the house in Craven Street, where Franklin used to live.

Franklin was born on January 6, 1706. (That is the date on the Old Style calendar, and corresponds to January 17 on the New Style calendar.) Biographical studies of Franklin are abundant, and a comprehensive survey of his scientific work can be found in J. G. Crowther's book *Famous American Men of Science*, for example. Franklin himself left behind him a very revealing *Autobiography* which is well worth consulting.

One of this year's commemorative lectures was delivered by Prof. E. N. da C. Andrade to the Royal Society of Arts on January 18. This dealt in particular with the periods which Franklin spent in London, and his connexions with both the Royal Society and the Royal Society of Arts.

Prof. Andrade mentioned Franklin's pioneer experiments on electricity, which started in 1746 when Peter Collinson, the F.R.S. who was one of his great friends, sent him a glass tube suitable for generating frictional electricity. In the course of this early work he made the first plane condenser using a sheet of glass sandwiched between two lead plates. To most people, his most famous experiment was the one with the kite which he described in the classic letter of October 19, 1752 This was only one out of the many which he made when investigating lightning phenomena. He had previously shown that thunder-clouds are seats of electric charge. In his lecture Prof. Andrade quoted Sir Oliver Lodge's judgment that "The proof that lightning was in fact nothing but a large electric spark was given in 1751 by that comprehensive and common-sense genius, the Philadelphian printer, Benjamin Franklin."

Franklin's pioneer work on electricity became known in Britain through his letters to Peter Collinson, which were printed in London as a pamphlet in 1751. Two years later he was awarded the Copley Medal, a fact that refutes the suggestion of some writers that the Royal Society scoffed at Franklin's earlier work. He was elected F.R.S. in 1756, and became a member of the Society's Council.

Franklin came to London in 1757 as the agent of the Pennsylvania Assembly, and during this stay he took rooms in the house in Craven Street. He was actively interested in the affairs of the Royal Society of Arts, which had been founded in 1754. He regularly attended meetings of the committee which was concerned with the colonies and trade, and frequently took the chair. This committee looked into many technical points in the agricultural field, and vigorously encouraged such colonial activities as production of dyestuffs, logwood and safflower, of silk, of olive oil, and of hemp. It also stimulated the production of potash in America and its importation into England.

His advocacy of pointed lightning conductors led to the famous episode when George III clashed with the Royal Society's president. A Royal Society committee had investigated the relative efficiency of blunt and sharp conductors, and its conclusions supported Franklin's view that high and pointed conductors showed distinct advantages. Franklin was then regarded by court circles as a rebellious American and an enemy of the crown, and this seems to have prompted royal representations to Sir John Pringle, the President of the Royal Society. Their implication was that the Royal Society should reverse its decision favouring the kind of lightning rod that Franklin advocated. Sir John Pringle then delivered his famous reply: "Sire, I cannot reverse the laws and operations of nature."

The friendships he formed in scientific circles in this country were numerous. The prominent men whom he knew well included Cavendish, Sir Joseph Banks, Joseph Priestley, James Watt, Herschel the astronomer and Josiah Wedgwood, the master-potter.

His work as an inventor deserves some mention. Bifocal spectacles is perhaps the best known of his inventions. His claims to fame as a skilful diplomatic negotiator and as a statesman are perhaps even more impressive, but these matters, to which full justice has been done in all of the biographies of Franklin are somewhat outside the scope of this short note.

"LUDDITES" OF THE ATOMIC POWER AGE

No final decision has been taken yet by the Ministry of Fuel and Power on the siting of nuclear power stations at Bradwell, on the Colne estuary in Essex, and at Berkeley, on the Severn, in Gloucestershire. There seems to be little doubt, however, as to how that decision will go. The local planning authorities, Essex County Council in the first case and Gloucester County Council in the other, have already signified their approval in principle. There has been some local opposition from individuals and organisations, it is true, but while these objections are regarded with sympathy they do not carry much weight. So far, the Atomic Age has not caused any substantial numbers of "Luddites", to emerge.

It might be said with some justification, in fact, that the Central Electricity Authority, which is the organisation most immediately interested in the plans for atomic power stations, is winning its battles too easily. Apart from the willingness of its information officers to supply facts and to talk to the representatives of local papers, very little has been done to persuade the local people of the merits of the schemes. The policy appears to be one of letting the merits speak for themselves and leaving it to the local inhabitants to discover what those merits are.

This attitude is very different from the policy of "educating the public" that has been adopted by the United Kingdom Atomic Energy Authority, which obtained such good results when a site had to be found for the breeder reactor at Dounreay, Caithness. On that occasion models of the new station were sent to the town, and senior officials of the authority, led by Sir Christopher Hinton, took great pains to explain to the local people what it was all about and answer all the questions that were posed to them. The result of this effort was to create a *demand* for the new establishment.

Although the first public announcement about the choice of the Bradwell and Berkeley sites was made months ago the CEA has only now arranged for a small exhibition at Bradwell to tell the local inhabitants what it is all about.

In the siting of any large power station an ample supply of water is one of the major considerations and it might be argued that, with the demand for power expanding as it is at present, a power station of some sort would have had to be built in both these places in any case if only because both of them satisfied this major consideration. Those who have gone into the matter would probably have no difficulty in deciding whether they preferred a "new era" power station of the atomic variety or one surrounded by railway sidings and heaps of coal and ash.

One of the main sources of anxiety about the nuclear projects stems, of course, from the fear that their presence might give rise to some risk from an atomic explosion or of gradual contamination by radioactive effluent. It is here that a good public relations job could be done by explaining that, at least in the case of the type of power station now envisaged, such fears are entirely groundless.

All the Central Electricity Authority nuclear power stations that are at present contemplated for immediate construction will be of the graphite-moderated gas-cooled variety. The reactors will be essentially similar to the power reactors of Calder Hall. This type of reactor can be built in such a way as to be inherently stable. Any abnormal rise in the rate at which heat is produced would thus automatically tend to reduce the rate of the atomic chain reaction, even if there were no mechanical safety devices installed for the purpose. The cooling gas is contained in a closed circuit and passes through a "heat exchanger" along the lines of some efficient tube boilers. It is steam produced in these heat exchangers that will be used to drive sets of conventional turbo-alternators. Almost all of the water needed in such power stations will be used for cooling purposes in this steam circuit. It will therefore have no chance to asquire radioactivity.

SCIENTISTS IN EXILE

In Britain notable names in the list of refugee scientists, who have made important contributions to atomic research include those of Prof. O. R. Frisch of the Cavendish Laboratory, Prof. Sir Francis Simon of the Clarendon, and Prof. R. E. Peierls. This parallels what happened in the U.S.A.: as Waldemar Kaempffert once wrote, referring to the American atomic bomb project, that the names of refugees made the list of nuclear scientists working on the American atomic bomb project look like an Ellis Island immigrant list.

Many more examples are provided in the Unesco report just published by the H.M. Stationery Office with the title *The Positive Contribution of Immigrants* (price 12*s.* 6*d.*).

A wide range of other scientific activities have been influenced by alien immigrants since 1933, and the report instances many important professorial chairs at British universities held by recent immigrants. The discovery of the curative properties of penicillin was due to a team headed by Dr. E. B. Chain and Prof. Sir Howard Florey, who shared the Nobel prize for medicine in 1945. Dr. Chain came to England in 1933. Another joint Nobel prize-winner was Dr. H. A. Krebs, professor of biochemistry at Sheffield, for his work on metabolism.

This publication is a symposium of reports on the U.K., the U.S.A., Australia, Brazil and the Argentine, prepared for Unesco by the International Sociological and Economic Associations,

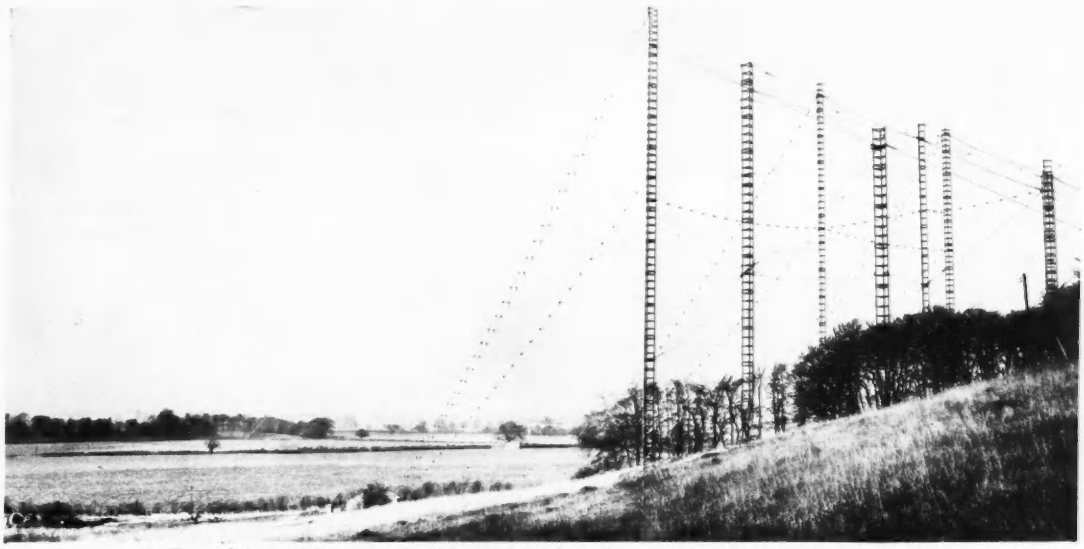

FIG. 1. Transmitting aerial array at the U.S. Air Force long-distance radio station at Kingston Blount, Oxon., from which signals will be projected into the ionosphere and "scattered" over Iceland. Two similar aerial systems for reception have also been erected.

"FORWARD-SCATTER" PROPAGATION

THE TRANSMISSION OF RADIO SIGNALS OVER LONG DISTANCES

Until comparatively recently the use of v.h.f. radio links for communication purposes has been limited roughly to visual ranges. It was thought that their quasi-optical properties would determine the distance over which reliable transmissions could be established, with the horizon as the end. Thereafter the signals, travelling in a straight line, would leave the earth's surface and be lost in space beyond. Thus point-to-point stages, usually covering ranges of about 30 miles, were necessary for greater distances; each relay station requiring a separate frequency channel in the v.h.f. band over which communications are transmitted at low power. The development of a high-power long-distance v.h.f. radio link system is therefore of considerable technical interest.

Such a system depends upon the new transmission technique known as "scatter propagation"; it is alternatively known as "beyond-the-horizon" or "extended-range" transmission. By this system signals directed into the ionosphere are scattered forward to reach the earth again at ranges of up to 1400 miles in one hop from the point of transmission. It provides a degree of reliability which is unattainable by other long-distance radio circuits, and the system is highly secure so far as the integrity of communications is concerned.

The first regular service to employ forward-scatter propagation has recently been brought into operation by the United States Air Force. This extends in single-stage hops from Limestone, Maine, in the U.S.A., to Goose Bay, Labrador, and then on through Sondrestrom in Greenland to Iceland. Thule, the U.S. Air Force base, and Narsarssuak in Greenland are also brought into the system by similar links. Early this spring the last link—between Iceland and Kingston Blount, Oxon. —will be opened, thus completing a highly important strategic link between this country and America. The system is capable of carrying at least eight teleprinter circuits and one voice channel, and two-way communications will be provided between the seven terminals and relay stations.

Brute force is the essence of forward-scatter propagation. It has been adopted by the U.S. Air Force because conventional long-range high-frequency techniques have so far failed to establish reliable radio service in the Arctic region, with its frequent magnetic disturbances. The new technique probably represents the most important advance in long-range radio communications in recent years.

Although the theory of forward scatter is not yet completely understood, there is ample evidence that the ionosphere and troposphere allow radio signals (in the frequency bands between 30 and 60 megacycles a second and 200–3000 megacycles respectively) to be

propagated over distances far beyond the horizon with losses much less than were predicted by the diffraction theory. Most of the development work on forward propagation by ionospheric scatter has been done in the United States during the last five years by D. K. Bailey, R. Bateman and R. C. Kirby, of the National Bureau of Standards, Washington; the Massachusetts Institute of Technology's Lincoln laboratory have also helped to perfect the system.

T. L. Eckersley first pointed out in 1927, in an article on "Short Wave Wireless Telegraphy", which was printed in the *Journal of the Institution of Electrical Engineers*, that as a result of his observations on short-wave scattering in the ionosphere it was evident that the E-layer was a complicated structure of ionic clouds which appeared to have some degree of permanence. These clouds, the ionised trails left by meteors and atmospheric electricity (particularly electrical discharges not necessarily accompanied by lightning), are regarded as the mechanism that makes it possible for v.h.f. transmissions over long distances to be achieved. It may well be, however, that an explanation for the v.h.f. scatter phenomena will be found eventually to be due to the effects of more than one agency. Whatever the cause, for all practical purposes it has been found that the lower ionosphere—in the region of the D-layer—when bombarded with a very powerful v.h.f. radio beam is sufficiently "opaque" to those frequencies to return a fraction of the energy focused upon it. By this means uninterrupted signals can be received, irrespective of season, time of day or magnetic disturbance, over distances of up to about 1400 miles.

Following on the work of Bailey and his colleagues, which greatly interested engineers concerned with the provision of long-distance point-to-point radio links, the Post Office decided to investigate at first hand the characteristics and possibilities of v.h.f. propagation by ionospheric scattering. In 1952 an experimental link was first established between a transmitting station in the Shetland Isles and a receiving station at Jersey in the Channel Islands, a distance of 740 miles. The Department of Scientific and Industrial Research, being anxious to assess the validity of the various theoretical hypotheses that had been advanced about scatter propagation, co-operated in the experiment, and they set up a second receiving station at the Radio Research Station at Slough, 580 miles from the Shetlands.

From a high-gain directional aerial system test transmissions were initially carried out on a frequency of 89·05 megacycles, a rather higher frequency than the Americans had used. This was done to avoid possible interference with television broadcasts. Experiments were afterwards made on 41·1 and 27·27 megacycles. Towards the end of 1953 the Admiralty provided H.M.S. *Fleetwood*, which had been specially equipped for the purpose, as a mobile receiving station which collected data on the range and beam-spread of the transmissions.

A further series of tests are being currently carried out by the Admiralty with a modified high-power television transmitter, installed at Gibraltar. This projects a beam of radio energy into the ionosphere somewhere over the Bay of Biscay, and the signals scatter over Britain, where the Ministry of Supply, the DSIR and the Post Office have set up special receiving stations to collect propagation data. These experiments are providing valuable information on the general characteristics of v.h.f. ionospheric scatter propagation. They have shown that a residual signal is always present, having amplitude and phase fluctuations which are indicative of scattering from a large number of highly variable scattering centres. In the British view the scattering is probably due to both ionospheric turbulence and meteoric ionisation, the relative importance of the two mechanisms varying from time to time but always contributing to the residual signal.

The first permanent long-distance v.h.f. transmitting and receiving station in Britain, at Kingston Blount, immediately claims interest because of the unusual aerial system, which is an essential part of the new communications technique. This U.S. Air Force installation comprises broadside arrays of four-in-line horizontal dipoles backed by a V-shaped reflecting curtain of wires; each dipole element resembles two cones base to base. In all there are three complete aerial systems, each about 160 feet wide, 90 feet deep and about 120 feet high; one will be used for transmission, the other two for reception. The photograph shows the transmitting aerial system (the three arrays are identical) on a northern slope of the Chiltern Hills with several miles of flat country ahead, a necessary requirement. It is directed to a zone 50 miles above the earth's surface midway between Oxfordshire and Iceland, from which the v.h.f. signals will make their ionospheric scatter on a 1200-mile journey between the two stations. About 50 kilowatts of energy will be radiated along a narrow beam at a frequency of 35 megacycles a second, and because the frequency band of the transmissions from the British terminal may interfere with local television reception the American authorities will provide special "noise-suppressors", designed to eliminate the nuisance should it arise.

Full information about developments in America, where the subject of forward-scatter has been most advanced, is being passed to the Air Ministry, and the Royal Air Force hope shortly to start work on the installation of their first long-distance v.h.f. link between this country and Malta, extending the system to Cyprus (another 1000-mile jump) and on to the Middle East, with a leg reaching across Africa and eventually perhaps to Australia and New Zealand. It would augment the RAF's already extensive communications network. Apart from providing a high degree of security, Air Vice-Marshal L. Dalton-Morris, Assistant Chief of the Air Staff (Signals), said recently that propagation by forward scatter from the ionosphere was inherently extraordinarily reliable, "a factor of better than 98% being achieved in service". This is a great improvement over normal high-frequency communications, which also involve several frequency changes each day in order to maintain contact throughout the system.

So much for the forward scattering of radio energy from the *ionosphere*. A somewhat similar technique.

known as *tropospheric propagation*, is also being rapidly developed in the United States. It is based again on fundamental research done in Britain. Further development work in this country is at present held up because of the lack of frequencies. The firms interested in it include Marconi's Wireless Telegraph Company, the General Electric Company, Standard Telephones and Cables, Limited, and the British Thomson-Houston Company. What is required now is the allocation of a band of frequencies before the key equipment (particularly the Klystron valve) can be developed on a commercial scale for the world-wide markets that are expected to open soon for the system.

Unlike ionospheric scatter propagation, which at present can only handle a narrow bandwidth, the system using the troposphere provides much greater scope. Already it links the Arctic defence ring of radar stations in North America. Because of the wide bandwidth that can be passed the system would be fully capable of carrying television programmes, instead of radar pictures. At the present stage of development tropospheric propagation can transmit a bandwidth of 7 megacycles —the BBC television picture requires a bandwidth of 3 megacycles a second—but it has been claimed that the system will soon be able to cope with a bandwidth of 20 megacycles a second.

Forward scatter from the troposphere is achieved by radiating energy in the 200–3000 megacycle band from a 60-foot diameter parabolic reflector. The beam is aimed as low as possible so that it can be projected back to earth from the most distant possible tropospheric region. Because the troposphere rises only about five miles above the earth's surface it follows that ranges are much less than when the ionosphere is used, and ranges of only about 300 miles are possible with present powers available in the aerial.

The system has been proposed in the United States as being suitable for relaying live television programmes from America to Europe.

Active research is continuing on forward-scatter techniques, and several new developments are in prospect.

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GRADUATES AND INDUSTRY

A letter sent to the Minister of Labour by the Federation of British Industries urges the Government to grant deferment of National Service, if requested, to all science and engineering graduates with 1st or 2nd class honours degrees who take up employment in industry, and to continue deferment so long as they remain in such employment.

The FBI Grand Council has for some years been much disturbed by the shortage of science and engineering graduates. At present the Government grants deferment to these graduates if they go into Government or Government-supported jobs related to the defence programme. In consequence, industry's share of this highly trained manpower has become so inadequate as to jeopardise both its ancillary work for Government projects and, of greater importance, its competitive position overseas.

After making these points, the letter continues as follows: "In the opinion of the Federation, the gravity of the position necessitates not only the avoidance of this distortion but also an increase in the overall availability of graduates even though this involves further encroachment on the principle of 'equality of sacrifice'. While the justice of that principle is apparent to all, the matter is seen in its proper perspective when it is realised that the entire annual output of science and engineering graduates is only $1\frac{1}{2}\%$ of the total number of men eligible for National Service, and of the latter some 50% are in any case not called up for one reason or another. It could well be argued that the country cannot afford the rigid adherence to principle which results in over half of the sorely needed graduate output being trained for service in the armed forces for which in the event of global war few of them could ever be spared."

The Federation appreciates the difficulties of exempting from National Service all these graduates, desirable though that may be. The situation is, however, so serious that it wishes to urge the Government most strongly to grant deferment, where requested, to all science and engineering graduates with 1st or 2nd class honours degrees who take up employment in industry generally as well as in Government establishments or on Government sponsored projects, and to continue deferment for so long as they remain in such employment.

WIND TUNNELS AND AEROPLANE DESIGN

A. E. KNOWLER, M.Sc., Ph.D. and C. M. BRITLAND, D.Ae.
Royal Aircraft Establishment, Farnborough

To help with the design of their aeroplane, the Wright brothers made some experiments in a wind tunnel as long ago as 1903. This early tunnel had a working section 16 inches square and a wind speed of 28 miles per hour. Eiffel, the designer of the famous tower, also made a wind tunnel. The development of the aeroplane during the last half century is well known; what is not so well known is the equally sensational development of the wind tunnel.

The basic idea of a wind tunnel, of course, is that the model is fixed and the air moves past it. Testing in this way has many advantages, notably that shapes that would not fly, like wings without bodies and bodies without wings, can be studied. Similarly aeroplane shapes can be tested in attitudes in which they would be out of control in flight. Further, the problems of measurements are made very much simpler as there is an unlimited amount of space outside a tunnel for the mounting of the instruments.

Tunnels can be classified according to their speed range. There are "low-speed" tunnels going up to about half the speed of sound, "transonic" tunnels working near the speed of sound and "supersonic" tunnels which run faster than sound. For various reasons it has been found convenient to introduce an additional term, "hypersonic", to refer to those tunnels which run at five times the speed of sound or more. These categories are not entirely arbitrary but are based upon physical changes in the flow: the tunnels in one category are quite different engineering structures from those in another. In low-speed tunnels most of the tunnel structure can be built of wood, but as the speeds increase, forces increase, so high-speed tunnels are built of metal.

TRANSONIC AND SUPERSONIC TUNNELS

In the neighbourhood of the speed of sound, shock waves appear, and transonic tunnels are specially designed so as to reduce the effects of the reflection of the shock waves from the wall and also other adverse effects which arise when a tunnel designed for low speeds is run up to the speed of sound. For supersonic tunnels the walls have to be specially shaped, a separate shape for each speed. The shaping is illustrated in Fig. 1. The chain-dotted line gives the shape of the liners for a speed of about two and a half times the speed of sound. The speed in the working section, which is roughly at the position of the observation window, is determined by the ratio of the area of the working section to that of the narrowest portion which is called the "throat": the higher the speed the narrower is the throat. When the speed is so high that it is in the hypersonic range, for a working section one foot wide the throat width may be only a few hundredths of an inch. In a hypersonic tunnel the air has to be heated, sometimes to several hundreds of degrees centigrade, otherwise it would liquefy in the working section. The kinetic energy of the air in this part of the tunnel is very high and comes from the total energy and so the temperature falls considerably.

Because current interest is focused on high-speed planes it does not mean that low-speed tunnels are obsolete. High-speed planes have to take off and land in the low-speed range and their special design features (e.g. swept-back wings) introduce new problems at low speeds. It is generally true that the higher the top speed of a plane, the greater are the problems at low speeds.

During the nineteen-twenties and thirties a good deal of wind tunnel research was devoted to establishing the effects of systematic variation of wing shape and cross section and various types of controls and flaps. Most of the work was done on isolated wings, or bodies. Supplementary tests on wings, bodies, nacelles, controls, etc., in combination helped to define the interference effects. A large body of data was built up which enables the aerodynamic design of conventional, moderate-speed aircraft to be placed on a reliable basis. Nowadays it is seldom necessary to carry out extensive wind tunnel tests on a medium-speed transport or private owner class aeroplane, although it is prudent to make tunnel tests on the near-final design of expensive projects like the "Britannia".

Today, the major part of low-speed wind-tunnel programmes is concerned with the testing of specific aircraft designs, while basic research is concentrated on the transonic and supersonic ranges.

In low-speed work, results obtained, say, at 90 miles per hour can be applied to flight at, say, 200 miles per hour by taking the forces as varying as the square of the speed. Above about half the speed of sound, say 400 miles per hour, this simple relationship cannot be used and tests have to be carried out at a series of Mach numbers (the Mach number is the ratio of the speed to the local velocity of sound). Tunnel testing at Mach numbers above half the speed of sound even when the flow is still subsonic increases the problems, notably those due to what is called "interference" caused by the tunnel walls and the struts which support the model. This "interference" can be illustrated in the following way. An aeroplane in free flight in the open air has a certain air-flow pattern around it. When the aeroplane comes in to land and flies very near the ground some of the air which would have been deflected downwards by the plane is restrained by the ground. This has repercussions on the flow in the immediate neighbourhood of the aeroplane and the forces on it are altered. In tunnels there is a similar constraint on the flow because of the presence of tunnel walls and supports. At low speeds this can easily be allowed for, but as the speeds approach the speed of sound the interference increases

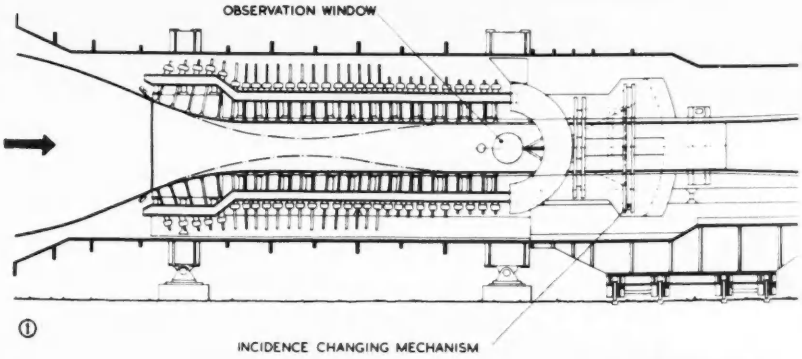
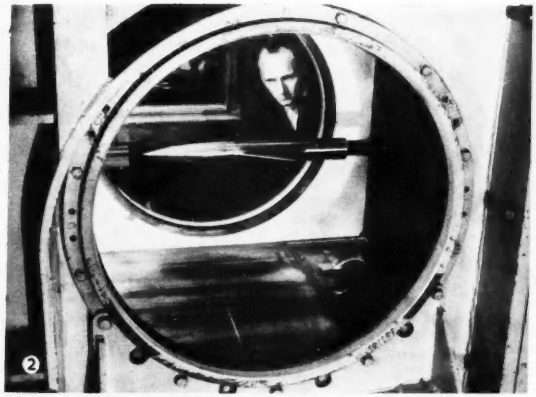


FIG. 1. A section through a supersonic tunnel with flexible walls, the position of which is controlled by screw jacks. The walls as illustrated would not give supersonic flow but when they are brought in to form a throat the flow becomes supersonic on the downstream side of the throat.



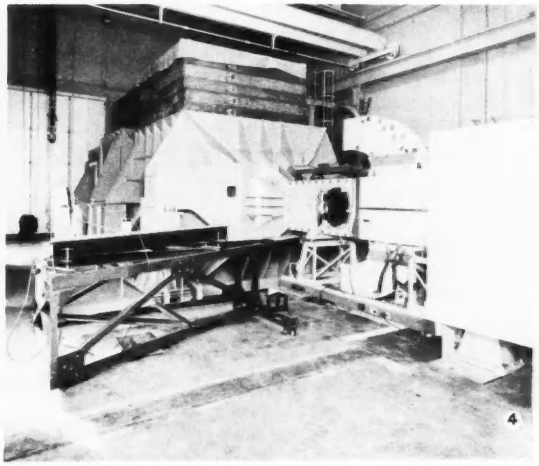
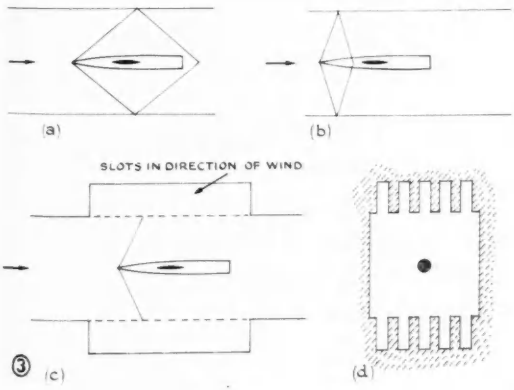


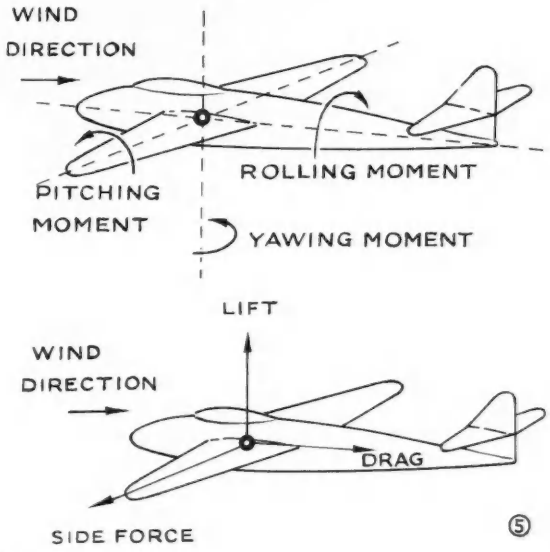
FIG. 2. The working section of a tunnel with a model in position. The windows are used for direct observations and also with Schlieren systems which show up the air-flow pattern.

FIG. 3. Sketches illustrating the reflection of shock waves from the walls of supersonic wind tunnels.

FIG. 4. Part of a supersonic wind tunnel at the Royal Aircraft Establishment, Farnborough, with a working section, 18 inches square. The bench in the foreground supports equipment which is part of the Schlieren system.

FIG. 5. Diagram illustrating the resolution of forces and moments on a model.





rapidly with Mach number and, because of mathematical difficulties, becomes less predictable. These complications, at least as far as the supports are concerned, have been overcome by the use of what is called a "sting support". This is illustrated in Fig. 2. The air flows from left to right and encounters the model before reaching the sting: the aft end of the model is where there is a sudden change in diameter, the narrow rod being the sting. The sting in turn is mounted on an incidence-changing mechanism such as is illustrated in Fig. 1.

When it was found that the forces on a model varied with the Mach number in an unsystematic way this led to the study of the behaviour of numerous wing and body shapes at high speeds. The interest now lay in thinner wings and more slender bodies than had been systematically tested at lower speeds. In addition, it was found that the mutual interference between the various parts of the model increased, so greater attention had to be given to the integrated design.

Now that the design speeds of a number of projected aeroplanes exceed the speed of sound, large "transonic" tunnels are being built. It is of interest to consider how the need for separate transonic tunnels arises. In a supersonic tunnel the shock waves which start at the head of a model (or indeed any other shock waves) are reflected from the tunnel walls in a way similar to that in which light waves are reflected from a surface. The faster the airstream the more sharply the shock waves sweep back: the waves in the tunnel of a Mach number of 1·5 are as illustrated in Fig. 3*a*. If the waves miss the end of the model the conditions are satisfactory for tests, even if they strike the support. At a Mach number of 1·1 the wave system is that illustrated in Fig. 3*b*: the reflected wave strikes the model, alters the flow aft of the striking point and the test is invalidated. In a transonic tunnel, steps are taken to suppress the reflected shock and to reduce the wall interference. This is done by having not solid walls on opposite sides but slotted walls like those illustrated in Figs. 3*c* and *d*. Fig. 3*d* is drawn looking in the direction of the wind stream. The principle involved in the action of slotted walls is the following: Three characteristic types of supersonic flow can be specified: steady uniform flow; shock waves in which the air is suddenly compressed and decelerated as the air passes through them; and expansions where the air is gradually accelerated, and rarefied as it passes through them. The tendency is, as might be expected, for shock waves and expansions to cancel each other out. The nose shock from the model is reflected as a shock from the solid slats, but at the slots it is reflected as an expansion. The two, cancelling out in whole or in part tend to suppress the reflected shock.

The part that supersonic tunnels are playing, apart from the fundamental study of the supersonic flow, is the study of the flow over models of guided missiles and the higher-speed aeroplanes. This kind of missile may travel as fast as 1500 miles per hour. Low-speed problems hardly exist for the missile as it is boosted rapidly to supersonic speeds and it has no landing problems, but there is no background of years of accumulated supersonic tunnel data and therefore much has had to be accomplished in the supersonic tunnel field in a very short time.

LARGEST BRITISH TUNNEL

An outstanding example of a supersonic tunnel is the one at the National Aeronautical Establishment at Bedford which has a working section measuring 8 feet square. When completed this will test at Mach numbers up to 2·5, which figure corresponds to sea-level flight at 1900 miles per hour. To give some idea of the size of this structure it should be mentioned that the compressor absorbs 80,000 horse-power, that the maximum diameter of the shell is 47 feet and its weight is 5000 tons.

It has been mentioned that in a supersonic tunnel opposite walls of the tunnel are formed by specially shaped liners (see Fig. 4). In smaller tunnels rigid liners are made for every Mach number and are changed whenever it is desired to change the speed: normally a pair of liners are used as illustrated in Fig. 1, but sometimes a single liner is used, the opposite wall being flat. In the 8-foot tunnel the weight of a pair of solid liners would run into tens of tons, and the frequent changing of these would involve severe engineering requirements. Instead, two flexible steel walls are used which can be bent into the desired shape by means of a number of jacks; these are shown in the figure. Each flexible "liner" is 62 feet long, 8 feet broad and 1 inch thick. The jacks have an elaborate control system which is required not only to set the wall to the required shape but also to avoid straining it beyond its elastic limit in the process.

For low-speed tunnels, the models are built of well-seasoned mahogany or teak which is laminated. In supersonic wind tunnels the forces are much larger and the local stress in the model can be as much as 10 tons per square inch and so the model must be made of high tensile steel. Great accuracy of manufacture is required for these high-speed models: an accuracy of 0·001 inch is sometimes called for.

It is now of interest to consider some of the types of measurement that are made in wind tunnels. With regard to the force acting on the model the aerodynamicist finds it convenient to split it into three directions at right angles and to treat them separately. This is illustrated in Fig. 5. There is the *drag* which opposes the motion, the *lift* which sustains the aeroplane, and the *side-force* which arises when the aeroplane yaws. The aerodynamicist does not want to know only the magnitude of the forces but also where they act. Clearly it makes a lot of difference to the flying qualities of the plane where the force acts in relation to the centre of gravity: accidents have been caused where, due to faulty loading, the centre of gravity has been wrongly placed in relation to the centre of air pressure. The aerodynamicist therefore measures the "pitching moment" (the moment of the lift force about some axis, which might be the leading edge of the wing), and a "yawing

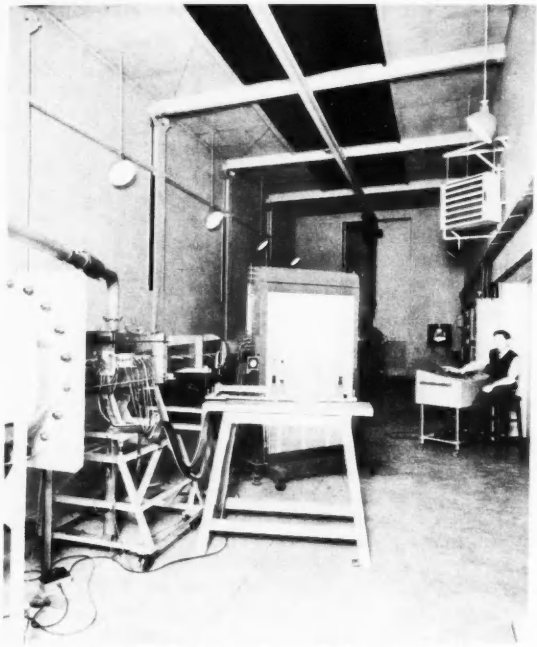


FIG. 6. A small supersonic tunnel in operation. Pressure distributions on the wall are being measured using the multiple manometer in the centre of the picture.

moment", in addition he measures the "rolling moment" about two axes at right angles to each other and to the pitching axis.

In modern tunnels there is a tendency to break away from the mechanical type of balance used in earlier wind tunnels. The newer balances are based upon the use of strain gauges. These are grids of fine wire which are cemented to a surface so that they stretch with the surface. The stretching makes the wires longer and thinner, and so their electrical resistance increases: this can be measured accurately, and so the gauges can be calibrated to give an accurate and convenient measure of surface strain. The splitting up of the force into its six components is accomplished with relative ease by the correct positioning of the gauges on the model support.

The stressman in the design office wants to know not only the overall forces on the aeroplane but also how that force is distributed about the surface: thus, if it is highly concentrated in a region he must take steps to ensure that that part is made stronger. In a wind tunnel not only the total load but also the distribution of load can be measured. Pressures on the model surface when mounted in the tunnel airstream can be measured using small-bore tubes which end flush with the surface and are connected to manometers (Fig. 6). In this illustration it is actually the pressures along the walls of a small tunnel which are being measured, but the method is the same where the pressure on models is being studied. The designer wants to know the pressure at as many places as possible, but in practice there is a severe limit to the number of tubes which can be built into the model. The model of a wing may be less than $\frac{1}{4}$ inch thick, and to make such a model with as many as seventy tubes running through it poses quite a problem.

AUTOMATIC RECORDING

As high-powered tunnels are exceedingly expensive to run, a lot of work has recently been done to record tunnel measurements automatically; this process has reached a stage where on the operation of a switch an electric typewriter types out the components of the force and simultaneously cards are punched so that the results can be worked out automatically on a Hollerith machine.

The simplest tests are those in which the model does not move relative to the tunnel wall and these tests correspond to steady flight conditions. In actual flight, complications arise when the aeroplane departs from steady conditions. Thus, if it is hit by a gust of wind it may quickly return to steady flight of its own accord. Great stability is not always a virtue, however; it may be on a trainer plane but a fighter has to manœuvre rapidly and this requirement tends to conflict with stability. The designer requires data that will enable him to calculate the subsequent motion of an aeroplane when it is disturbed either by a random gust or by a deliberate change in the setting of a control. A large amount of information on the dynamic behaviour of an aeroplane can be deduced from tests on a fixed model, but sometimes dynamic tests on a model need to be made. In such tests the model may oscillate about a traverse or vertical axis, or it may be rotated continuously about its own longitudinal axis.

A tunnel model is normally solid and is therefore very rigid. It is very different in this respect from an actual aeroplane, which has to be a light structure and therefore has to be built up of relatively light frameworks with a covering skin. This leads us to the inevitable fact that when an aeroplane is flying it is not exactly the same shape as when it is standing on the ground. For example the lifting force on the wings causes them to bend upwards from the wing roots. This bending is not usually noticeable to the passengers, but the designer has to be able to calculate how much the distortion affects the flying of the plane. In such respects the model and the aircraft behave differently, and hence the tunnel tests made on a rigid model will give a slightly incorrect answer.

On the other hand, useful information about what is known as "flutter" can be obtained from wind tunnel experiments. If a metal bar is clamped in a vice, pulled aside and released it will perform flexural vibration: if a weight is hung on a wire, the wire twisted and then released it will perform torsional oscillations. An aeroplane wing is capable of vibrating in both these ways. In flight both types of oscillation can occur, and when they do serious flutter can result. Severe flutter can even cause a wing to break up in the air. Tests can be

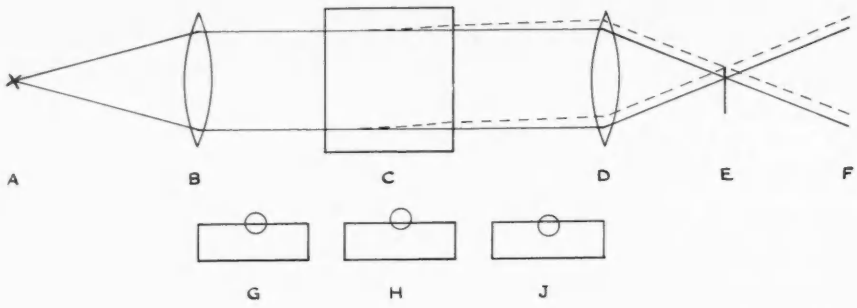


FIG. 7. DIAGRAM ILLUSTRATING THE ACTION OF A SCHLIEREN SYSTEM

made in a tunnel to find out whether a particular wing or control flutters or not, and they can also indicate how flutter can be avoided. The model in a "flutter" test must be built to have the right stiffness; it is also provided with adjustable weights inside it as the distribution of weight alters the chance of flutter and by finding the most suitable position of the weight in the model the designer can find how to avoid flutter in the aeroplane. In the tunnel test it is not the forces one aims to measure, but the modes of vibration of various parts of the model. Mechanical links cannot be taken into the tunnel to make up and measure the vibration of the model surface, but small mirrors can be let into the surface and a beam of light directed on to the mirror: the vibration of the surface can be judged by recording the trace of the reflected beam.

UNDERSTANDING THE AIRFLOW

So far we have dealt more with the needs of the designer, who is concerned mainly with the forces and moments on the aeroplane and only indirectly with the airflow patterns over the aeroplane or with the mechanisms of fluid flow which cause those forces. The scientist wishes to extend his theories of fluid motion, and though his contribution to design is not direct it is nevertheless considerable. The wind tunnel is exceedingly important to the theoretical man as it provides a check on his results and a large amount of tunnel work, mainly in Government establishments, is directed to this end. These experiments tend to be not on models of complete aeroplanes but on simple shapes such as flat plates, cones and cylinders, and aerofoils which completely span the tunnel.

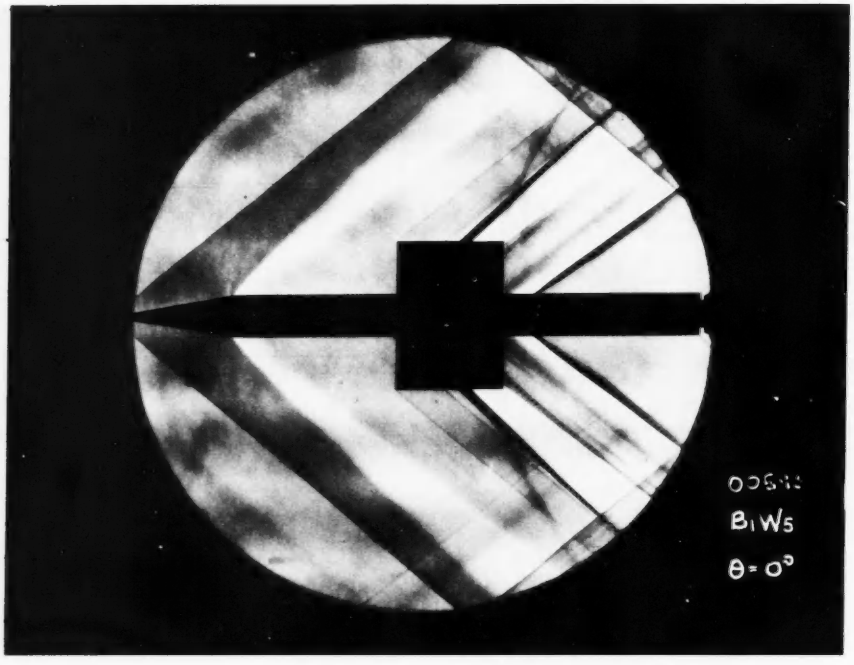


FIG. 8. A Schlieren picture of the flow round a model in an airstream at a Mach number of 1·6. The waves reflected from the tunnel walls can be seen.

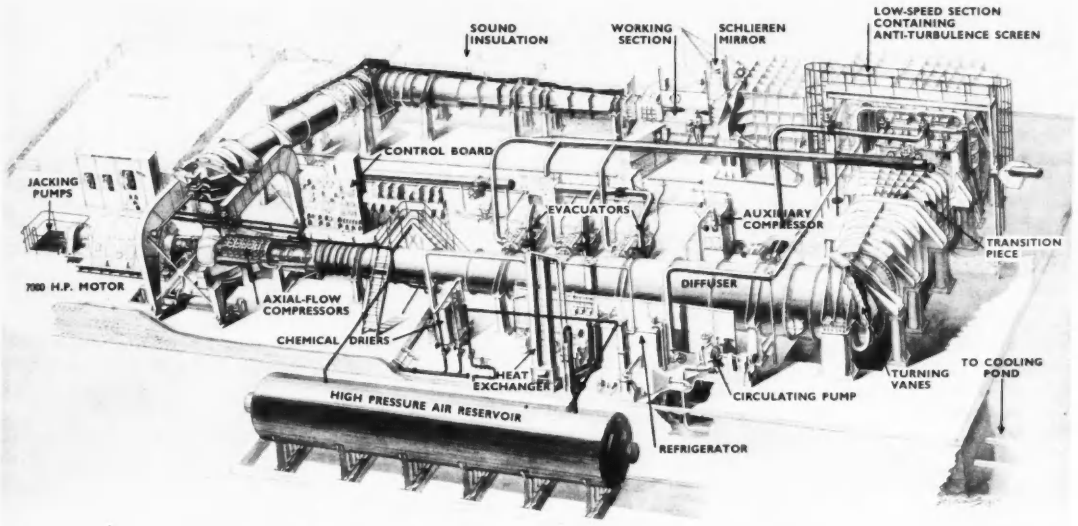


FIG. 9. A drawing of a supersonic wind tunnel at the Royal Aircraft Establishment, Farnborough.

An example of this more fundamental work is the illustration of airflow patterns. Such patterns are sometimes shown up in nature by sand or snow. In a low-speed wind tunnel a visible smoke like titanium tetrachloride is injected in the airstream, the movement of which can be watched or photographed. It is injected either just ahead of the model or through a slot on the surface of the model itself. Alternatively, one can use tufts of wool or cotton attached to the surface: when the flow is streamlined they lie along the surface in the direction of the stream and when the flow is irregular the threads move rapidly about in a random fashion. At very high speeds neither of these techniques is suitable: the smoke blows away too rapidly and the threads break off. For higher speeds, other indicators are available like a mixture of lampblack in oil which will indicate the flow on the surface itself. The flow near the surface of an aeroplane greatly affects its flying qualities. Near the forward part of the wing the layers of the "boundary layer" glide smoothly over one another to form what is called "laminar flow" and there is not much skin friction. This flow is very unstable, however, and is upset by roughness of the wing and some of the pressure gradients near the surface. This causes the flow to become "turbulent" and the skin friction goes up many times. The boundary layer may even separate from the surface leaving a "bubble" of stagnant air between the wing and the stream.

At transonic and supersonic speeds the local air density varies rapidly with local changes in speed around the aircraft or model: its refractive index in turn varies with the density and this gives us a method of showing up flow patterns by optical means. One method is the Schlieren system, the principle of which is illustrated in Fig. 7. An example of a Schlieren photo is shown in Fig. 8.

TOWARDS THE FUTURE

Now that aeroplanes are being designed to fly much faster, the "heat barrier" is becoming a serious problem because the heating goes up roughly as the square of the speed. The usual way of measuring the heat transfer from a moving airstream in a tunnel to the surface of a model is by burying thermocouples to known depths in the model which is made from a material with well-defined thermal characteristics. To measure the heat transfer at a single place on the model is not very difficult, but the designer wants to know how it varies from place to place on the aeroplane and for the same place how it varies with speed and altitude. The scientist builds up the laws of heat transfer by studying the problem with simple forms such as flat plates and cones and he relates the heat transfer to the velocity, the characteristics of the boundary layer and of the flowing gas.

It seems a far cry from the Wrights' home-made tunnel to the massive counterparts of today which have cost millions of pounds to build. In the interim the wind tunnel has become indispensable to aeronautical research, and that is likely to be the case for many years to come.

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DETERGENTS AND HOW THEY WORK

N. PILPEL, B.Sc., Ph.D.

According to the *Shorter Oxford Dictionary* a detergent is anything that cleans, but for most people the word has become associated with certain synthetic compounds that have been popularised as substitutes for soap in the last ten years or so. The fact is, however, that soap itself is a detergent, the earliest one that was discovered and therefore the best known, and the newer materials that have come on the market in such profusion are simply close relatives to it.

The detergent family is a very large one. It comprises thousands of different compounds, possibly hundreds of thousands, and new ones are continually being discovered. But for the purpose of understanding how detergents work we need consider only one trait which is common to the whole family. This is that all the members possess the same kind of molecular structure.

The molecules of all detergents are made up of two portions. The first portion can be termed the "head", the second portion the "tail". The simplest detergents consist of one "head" joined to one "tail". Examples of these are sodium stearate (ordinary hard soap), sodium octyl naphthalene sulphate (a synthetic detergent used for scouring textiles), and cetyl trimethyl ammonium bromide (another synthetic detergent which is used for cleaning and also as a disinfectant). The "head" and "tail" arrangement in these compounds is illustrated in Fig. 1. The molecules of other detergents may possess more than one "head" and/or more than one "tail", but this does not alter the essential fact of the duality in their structure.

The "heads" of detergent molecules are very approximately spherical in shape and have diameters of the order of 2×10^{-8} centimetre. The "tails" on the other hand consist of long chains of carbon and hydrogen atoms and have lengths of about 2×10^{-7} centimetre or more. The molecules may thus be pictured as being tadpole-shaped (Fig. 2). To some extent the tails are flexible and under certain circumstances can bend or coil up. But it would be pressing the analogy altogether too far to suggest that the molecules move through a liquid like tadpoles by wriggling their tails.

A fundamental difference between the "heads" and the "tails" is that whereas the former have a strong affinity for water, the latter are essentially "oily" and would not, on their own, dissolve in water.

When a detergent is added to water the "heads" tend to dissolve, that is to say they tend to spread out and distribute themselves uniformly through the liquid so that a maximum area of contact is established between themselves and the water (Fig. 3).

The "tails" on the other hand are "insoluble" and possess no such tendency to spread. On the contrary they tend to arrange themselves in such a way that the area of contact between themselves and water is reduced to a minimum. This is achieved in two ways. At the boundary surfaces of the water the "tails" actually emerge and either stick up into the air (at the air-water boundary) or attach themselves to the walls of the containing vessel (at the vessel-water boundary) (Fig. 4). In the interior of the liquid, on the other hand, the "tails" bunch together to form small spherical aggregates of molecules (other shapes have also been postulated). In the aggregate the "tails" are all coiled up together in the centre while the attached "heads" remain on the outsides of the sphere maintaining their own contact with water and at the same time shielding the "tails" from it (Fig. 5). By these two devices maximum contact is maintained between the "heads" and water while contact between the "tails" and water is kept to a minimum.

The layer of detergent at a boundary surface of the water is one molecule thick (hence it is called a *monolayer*) and is too thin to be visible even under the microscope; the molecular aggregates in the interior are also too small to be seen. Thus a detergent dissolves in water apparently in the same way as common salt or any other simple chemical. But by employing refined physico-chemical techniques it is possible to detect the molecular aggregates as well as the monolayer, and it is now known that these are responsible for the ability of detergents to clean.

CLEANING MECHANISMS

Cleaning is in many ways a complex process and may involve a variety of mechanisms which depend not only on the particular detergent that is being used, but also on the object to be cleaned, the nature of the dirt, and on the external conditions (e.g. temperature, presence of salts in the water, acidity) that prevail. Let us concentrate on a simple example that allows us to ignore some of these aspects; for instance we may take as an ideal case the washing of a piece of fabric the surface of which is covered by a thin layer of grease.

Under normal circumstances the grease would act like a waterproof skin preventing intimate contact between the fabric and water and therefore preventing it from becoming wet. But when the material is immersed in a detergent solution a new boundary is formed. Before there was only an air-water boundary and a vessel-water boundary. Now an additional grease-fabric-water boundary has been formed. The detergent molecules in the aggregates are strongly attracted to this boundary since by here orientating themselves as a monolayer they can still further reduce the contact area between their "tails" and water, and they therefore migrate to it. The "tails" displace some of the grease, and this begins to roll up. Its place is taken by an orientated monolayer of detergent, the "tails" attached to the fabric, the "heads" sticking into the water (Fig. 6*b*).

Now whereas before the surface of the fabric was separated from the water by a layer of grease having a thickness of say 10^{-3} centimetre, it is now separated

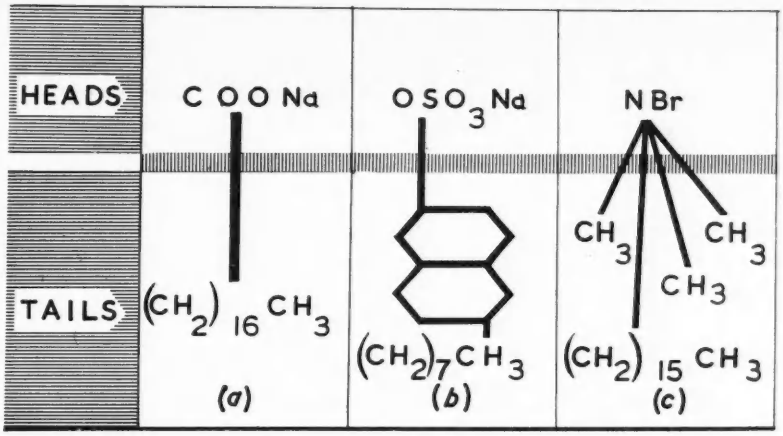


FIG. 1. The "head" and "tail" structure of three detergent molecules. (*a*) sodium stearate; (*b*) sodium octyl naphthalene sulphate; (*c*) cetyl trimethyl ammonium bromide.

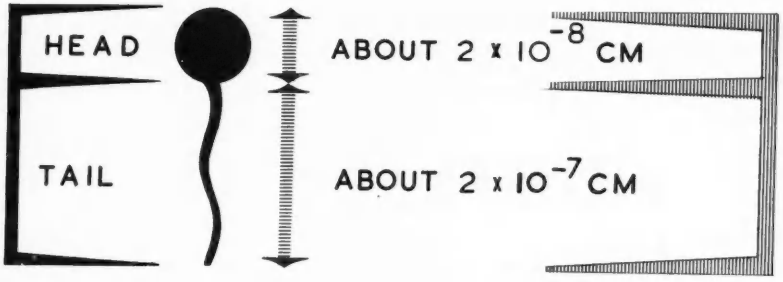


FIG. 2. Schematic diagram showing dimensions of sodium stearata molecule. The cross section of the tail is about 2×10^{-15} square centimetre.

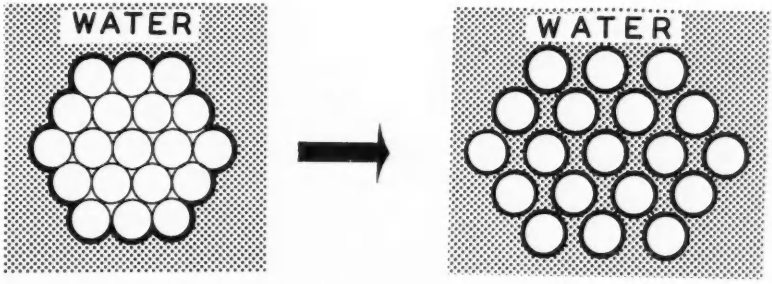


FIG. 3. This shows how the area of contact between the detergent "heads" and water increases as the detergent dissolves. (To avoid confusion, the "tails" are not shown.)

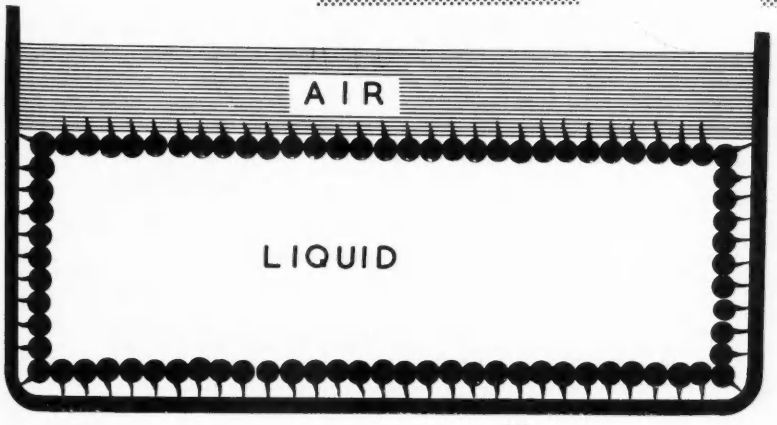


FIG. 4. Detergent molecules orientated at boundaries.

FIG. 5. Aggregate of detergent molecules in the interior of the liquid.

from it only by a monolayer of detergent whose thickness is of the order of 10^{-7} centimetre. To all intents and purposes close contact has been established between water and the fabric, and it becomes wet.

The grease meanwhile rolls up until small globules are formed (Fig. 6*a*). These have only limited contact with the surface of the fabric and are readily displaced by rubbing or shaking and float off into the surrounding liquid.

Now the surface area of a lot of small globules is much greater than that of the same quantity of material when it is spread out as a thin film. So the formation of globules results in a considerable increase in the total area of the grease-water boundary. Molecules of detergent from the spherical aggregates are attracted to the new boundaries and each globule becomes enclosed in a monolayer of detergent, the "tails" penetrating into the grease, the "heads" remaining on the surface and in contact with the water. This is shown in Fig. 7. The interior of each globule retains its greasy, insoluble characteristics, but due to the presence of detergent "heads" the surface acquires an increased affinity for water and this enables the globules to remain freely suspended in the water with little tendency to coalesce or to redeposit on the fabric. This arrangement of small floating globules of grease is known as an emulsion. When the fabric is lifted from the bath the emulsion is left behind and subsequent rinsing with clean water removes the last traces of it from the material.

In addition to being emulsified, some of the grease actually dissolves in the detergent. This process is illustrated in Fig. 8. Individual molecules of grease penetrate into the centres of the detergent aggregates that still remain and, as a result, each aggregate swells (compare Figs. 5 and 8). This increase in size has been detected by experiments employing x-rays and by other techniques. Emulsified and dissolved grease are really in very similar conditions, for in both cases grease has been imprisoned within a monolayer of orientated detergent molecules. The only difference is in the size of the resulting structures. A detergent aggregate enclosing grease is only slightly larger than the original aggregate, but the globules in an emulsion are considerably larger (compare Figs. 5, 7 and 8) and impart to the washing water the well-known turbid or misty appearance.

During the washing foam is produced and it is now known that this plays a part in removing the grease. The main action of the foam is in breaking up the larger globules of grease that have been liberated into the water. The foam consists of small bubbles of air surrounded by water, and the detergent molecules form an orientated monolayer at each air-water boundary producing somewhat the same effect as an elastic skin which prevents the air bubbles either from coalescing or from escaping into the atmosphere. The grease tends to accumulate at the junctions of the foam bubbles. When the bubbles burst the grease is broken into fine globules which can then be emulsified or dissolved by the detergent in the manner which we have already described. At one time it used to be thought that efficient cleaning only occurred in the presence of large amounts of foam, but it is now established that many excellent detergents produce hardly any foam. Traditions, however, change slowly and many manufacturers still find it politic to incorporate special foam-producing substances in their products.

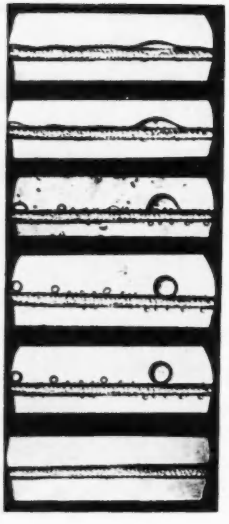
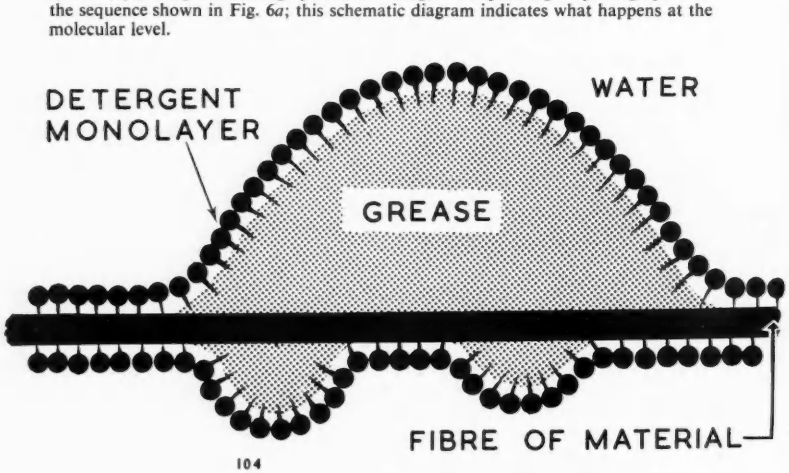
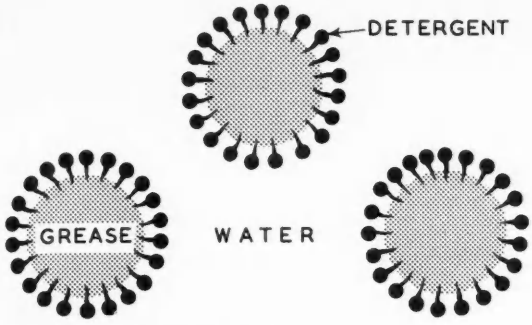


FIG. 6*a* (*left*). Stages in rolling up. FIG. 6*b*. Stage corresponding to photograph 3 in the sequence shown in Fig. 6*a*; this schematic diagram indicates what happens at the molecular level.





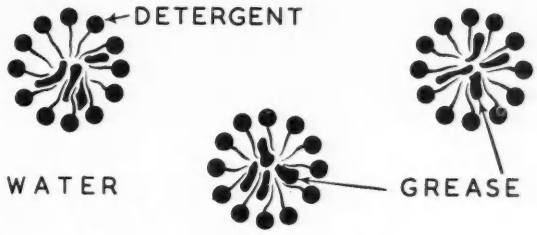


FIG. 7 (*left*). Emulsification of grease by detergent.
FIG. 8. Solubilisation of grease by detergent.

BLENDED DETERGENTS

The detergents that one buys in the shops are not quite the same as the chemicals that we have been talking about. Commercial detergents are blends and they contain, in addition to the substances whose molecules possess the "head" and "tail" structure, other chemicals which are added for a variety of reasons Of these chemicals phosphates, silicates and derivatives of cellulose are the most important and make up almost 70% (by weight) of the contents of a packet of commercial detergent.

Phosphates and silicates assist cleaning in a number of ways. They render hard water soft; they also make the solution more alkaline and this helps both in the initial wetting of the fabric and in stabilising the emulsion or solution of the grease. There is some evidence now that phosphates and silicates may enter into the structures of detergent monolayers, though how this affects the cleaning is not yet clear.

The cellulose derivatives likewise serve a number of purposes, particularly in preventing emulsified grease from redepositing on the fabric. They give the detergent blend its smooth-flowing qualities so that it may be poured conveniently from the packet, and they prevent it absorbing moisture from the air which could cause it to clog or cake.

Other substances that are frequently added to commercial detergents in small amounts include foaming agents, fluorescent dyes, fatty alcohols and perfume.

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THE MAN WHO DISCOVERED CARBORUNDUM

Two products of the electric furnace, the one being very hard silicon carbide or carborundum, the other graphite of extreme softness, owe their development on a large scale to one man, Edward Goodrich Acheson, who was born in Washington on March 9, 1856. Other workers independently hit upon the preparation of these products; yet Acheson deservedly gets full credit, especially so in the case of carborundum. This discovery of Acheson led to the carborundum grinding-wheels which revolutionised the machining of metals in the engineering industry. While several versions of the Acheson story hint at some element of chance or luck in his preparation of silicon carbide, or at times state that he was looking to the production of artificial diamonds, the truth is that this versatile man was looking for a good abrasive while studying the reduction processes using coke.

At the age of thirty-five, he made some experiments which resulted in his discovery of carborundum. His heating of clay and coke in a plumber's pot was intended to "harden" clay, an idea which came to him while working on the reduction of iron ore. He had appreciated the need for a good abrasive of moderate price; and when the silica in clay reacted with excess carbon in his electric furnace he produced silicon carbide. This product he named "carborundum" rather than Achesonite, thus bringing the name into line with corundum or hard alumina. Acheson had such difficulties in developing the commercial production of this exceedingly hard substance, particularly since there were rival claims, that eventually he turned his attention to a related subject, the production of artificial graphite. From the carbon vapour evolved on heating silicon carbide in the electric arc, graphite crystallises, with anthracite as his raw material, Acheson developed and patented in 1896 his process for producing graphite and adopting it for crucibles, refractories, and for lubricants when in colloidal form.

Acheson was awarded the Count Rumford Prize (for his electric furnace products), the Perkin Medal of the Society of Chemical Industry and the John Scott Medal.

M. SCHOFIELD

JOHN DIEBOLD "ELDER STATESMAN" OF AUTOMATION

MAURICE GOLDSMITH

I had expected to find something of the fanatic qualities of the prophet in the inventor of the term "automation". Instead, I found in John Diebold a charming, young, light-hearted American—incredibly, "the elder statesman of automation" is only 28—even although it was 8.30 in the morning when I met him for breakfast. He had just returned from talking to a group of British managers in Harrogate, where I had seen him in action, and very impressive he was too. Information, factual and ranging over a wide field, flowed from him without arrogance.

His book *Automation* is already a classic, and it is hard to believe that it was written four years ago. It does indicate the measure of the man.

Diebold agrees that the more we talk about automation, the less confidently we can assume a common understanding of the term. The word has come to mean so many things to so many people that for the moment he suspects it is losing a good deal of its usefulness.

This was Diebold's first visit to Europe, and he was interested to find that automation has become an issue, as it has in the U.S., and that it was too often discussed with less regard for the facts than for the particular preoccupation of the speaker.

For him, automation implies a basic change in our attitude towards production. Mechanisation did not change production based on the concept of the division of labour according to skills. Machines were introduced into the process structure in the main precisely as that structure had been designed around human skills.

Yet it is a very simple fact that the most efficient use of machines has little to do with the most efficient division of human skills. Until recently, this was one of the paradoxes inherent in the nature of mechanisation.

With the introduction of the new concept and technology of self-regulating systems, however, it is no longer necessary to design the production processes around the limitations of human skills.

But automation is much more than the technology of feedback. It differs from mechanisation in the very way that it regards the problem of production.

For Diebold, automation requires us to view the production processes as an integrated system and not as a series of individual steps divided according to the most economic distribution of human skills, or even of individual machines. Automation is a way of thinking, a way of "looking at", as much as it is a way of doing or a specific technology. It is an attitude—a "philosophy" of production, if you will—rather than a particular technology or electronic device.

He has searched for a long time for a definition that would be of use to him in an operational way, as a guide in his everyday task of planning changes in factories and offices. For him, automation is a means of analysing, organising and controlling industrial production processes to achieve optimum use of all our productive resources, mechanical and material as well as human.

Whether the product be a cylinder head, a radio receiver, a synthetic fibre or information, it is a concern with the production process as a system, and a subsequent consideration of each element as a part of that system. In planning for automation primary attention is

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directed towards the system, and the task of integrating the separate elements into the system. The whole problem of production is approached anew—even the product is reappraised in terms of its function and the functions of the machines that handle it.

The chemical industries provide many ideal illustrations of processes that have advanced to the second phase of automation. They have completely changed the nature of their process from "batch" to "continuous flow" to allow a high level of automatic operation, instrumentation and control. They are now beginning to achieve a higher level of automation: the integration of separate control functions into complete self-regulating *systems* in which the optimum relationship of variables is maintained by a continuous comparison with the desired qualities of the end-product.

In considering the application of automation, there were seven basic principles which guided Diebold. These are as follows:

Question every aspect of production: The most valuable asset to anyone in planning for automation is a questioning mind. Question not only the way you are doing things but your very reason for doing them.

Choose your timing carefully: For every process there is, at any given time, an optimum degree of automation, which is limited in part by the level of mechanisation of the process, and in part by the economic factors involved. New machinery is being developed constantly. Mass production techniques are decreasing the costs of older machinery. The difference of a few months may completely change the picture. Can you afford to be the first in your industry to introduce automatic equipment and the possible development costs connected with it? Can you afford *not* to be? What kind of equipment is available? What kind being developed? Would it pay you to attempt to develop on your own?

Make careful cost studies: It is foolishly naïve to approach automation strictly from the labour-saving viewpoint. Just as important are the economies achieved by increasing the amount of usable output—i.e. decreasing waste and improving the quality (in terms of uniformity and reliability) of the product. The justification of automation is in many cases—notably the process industries—that it decreases capital investment per unit of usable output, thus increasing the productivity of capital equipment. Capital expenditures are not, however, the only consideration.

Of equal significance are a range of other costs. These include: the analysis, the planning and the development of the system and the possibility that it may become obsolescent very soon if flexibility is not an inherent part of it. More highly skilled workers will be needed to run the system, and this implies training and special recruiting and also higher salaries. In addition, maintenance costs are likely to be higher: not only direct maintenance, but also because breakdown will affect the whole line.

None of these factors is to be considered as a disparagement of automation; nevertheless, they must be considered.

Organise for basic change: Planning for automation should be broad enough and should be done at a high enough level, so that a perspective can be maintained of the automated portions in relation to the rest of the operation. Automation of a segment of an organisation does not make it an island unto itself, and the fact of its automation may affect both its customer and supplier departments.

"Rethink" the product: We must question every element in the design of a product to determine if it is thoroughly suited to automation. Always ask yourself: Should I try to manufacture this product automatically, or should I alter the product so that it performs the same functions but is more suited to automatic manufacture? Product redesign, for the purpose of automatic production, takes many forms. It can be as simple as casting one or two reference points (such as small holes) on a part; on the other hand, basic redesign along completely new lines may be required. The product designer must be trained in the new engineering and manufacturing methods of automation and must work in close co-operation with the machine designer.

Reorganise the production process: Examine present processing methods to determine how, by either process or product redesign, they may be more closely integrated. Automatic processing should be continuous and progressive wherever possible. In this regard many rules come to mind; for example, a part, once gripped, should never be released until its manufacture is complete. Each time a part is released, it requires transfer and reorientation by a man or by additional machinery, and minimises an important advantage of automation: the reduction of in-process inventory. Consider at what points inspection stations should be incorporated into the system, what kinds of measuring devices may be used, and how the information from these inspections may be included in the feedback loops of the machines involved. An automation line, in the most significant sense of the word, incorporates inspection stations after each change in the product and links these inspection stations directly to the control of the preceding and of the subsequent phase. It is impossible to overestimate the importance of regarding the entire process as a system.

No list of automation principles can be complete: You cannot impart, through any list of principles, the engineering and management insight and genius that ultimately determine the success or failure of an automation programme. Any approach to automation depends, in the end, on the skill and understanding of the men involved.

For Diebold, automation brings no threat to the national economy. On the contrary, he believes it will give us enormously increased productivity. It will not bring unemployment. It will cause us to reconsider our whole approach to work. It will raise sharply many problems of education.

As we finished our coffee, Mrs. Diebold came in. We rose and she said: "John, it's time to go. We must have a look at the new integral calculator by ten o'clock."

I said: "More automation?" Mrs. Diebold smiled: "Yes, a horrible word—but our own, you know."

A transfer machine for machining cylinder heads at the Minsk Tractor Factory.

SOVIET AUTOMATION AT FIRST HAND

S. LILLEY, M.Sc., Ph.D.

Dr. Lilley has visited some automatic factories in the U.S.S.R. and in this article he gives some impressions of what he saw. Russia now has a special Ministry dealing with automation. Sir Walter Puckey, the well-known consultant on Automation, has kindly agreed to contribute to a future issue of DISCOVERY *a stimulating article. In it he will discuss the possibilities of using automation techniques in many different fields, away from the factory floor.*

My article in DISCOVERY seems to have given some people the impression that—in my view—the U.S.S.R holds an absolute lead over the rest of the world in the application of automatic processes. Actually my belief then was that the Soviet Union has a good deal less automation that we have in the West, but that their most daring experiments are much more completely automatic than anything to be found elsewhere. My visit to that country during the summer fully confirmed that estimate.

The bread-and-butter of automation in the engineering industry is, of course, the transfer machine. These are rapidly becoming common in the car industry for machining cylinder blocks, gear-box casings and the like. So I naturally made tracks for the Stalin Automobile Works in Moscow, where 42,000 workers turn out 120,000 vehicles a year (mostly heavy lorries and buses), besides 40,000 refrigerators and 400,000 bicycles. The factory dates from the First World War, and the first sight of it was very disappointing—the buildings were old, and rather dingy. Inside, however, I found that the general technical level was comparable to that of a good British car factory. Their transfer machines were of similar quality—one doing gear-box casings, with one operator, replaces fifteen standard machines and their operators; another does 380 operations on engine blocks, which are completed at the rate of 35 per hour. *But* they had less than a dozen transfer machines, whereas some British factories have a hundred or more. And even if one allows for the fact that there are more advanced Russian car factories—the Molotov Works at Gorki, for example—it remains clear that the U.S.S.R. has far fewer transfer machines than the U.S.A., probably considerably fewer than Britain.

As soon as one passes beyond the simple transfer machine for working monoblocs, Soviet achievement becomes more interesting. When I visited the Stankokonstruktsia Machine-Tool Building Factory—a first-class establishment—they were nearing the completion of an automatic line for machining tractor piston rings. On cylindrical fixtures holding twenty-four at a time, the rings pass through a series of stations which cut the gap, press the rings to close the gap and adjust the degree of spring, grind both internal and external surfaces (grinding stops automatically at the right diameter), groove the external surface of one ring in four, finish grind the surfaces, inspect all measurements (with automatic ejection of rejects), grease the rings, wrap them, box them, and load them on to a conveyor to the store. Labour requirements are reduced from twenty-five to three. Several such machines are already in use. I also saw plans and photographs of an automatic line for turning and assembling (but not, of course, winding) armature shafts. Two workers, in place of a former thirty, turn out three hundred a day. Again, several such lines have been in use for some years.

Processes like these, which involve turning and grinding, are recognised as being more difficult to automate than the milling, drilling, boring and reaming processes of the simple transfer machine. It is only in the last two or three years that they have been automated anywhere on a significant scale. And—while admitting that it is exceedingly difficult to judge—I estimate that the Soviet work is on a par both quantitatively and qualitatively with that of any other country.

So far, then, there is no sign of any general Soviet superiority. On the other hand, Russia has a few extreme examples of automation that are, I think, unrivalled. One of these is a new shop at the Kaganovitch First State Ball-Bearing Factory in Moscow—an establishment with a very progressive policy. In my earlier article, I described briefly how they had adapted a lot of very old multi-spindle automatics to make a completely automatic shop for machining bearing races. As the Director piloted me round the factory, I was lucky enough to recognise this shop at first sight. I produced a copy of my article from my pocket, and pointed out to him the paragraph referring to this production unit. He and his assistants were obviously immensely pleased at this indication that their work was known in Britain, and there was an immediate increase in the enthusiasm with which they took me on to see their new shop, based on this earlier experience, which was at that time working under test conditions.

This shop does almost the complete process of manufacturing ball-bearings and roller-bearings automatically. The blanks for the races, coming from the foundry (which is highly mechanised, but not automated) are tipped into hoppers. Conveyors carry them to a group of multi-spindle automatic lathes, where all the turning and grooving operations are done. The machined races are then passed through a complicated heat-treatment, after which they are automatically demagnetised. Then follows the grinding of all the faces and grooves to give the required accuracy, and polishing to give fine finish.

After washing, the races pass on to an inspection station, where thirty dimensions are checked. Rejects are classified into different channels according to what fault is discovered, so that it is easy to discover which machine is misbehaving. As part of the test, all these inspections were being manually checked, and the result was a most vivid demonstration of the labour-saving powers of automation—for about a dozen girls were working full out, with clock-face micrometers, to keep up with an automatic inspection station not much bigger than an office desk.

From inspection, the races pass on to the assembly section, where they meet the balls and separators. These are supplied from other shops, where production is presumably less automatic as yet. All the components are automatically assembled to make complete bearings. The assembly mechanism contains an interesting device for giving the finished bearings the permitted play of 6 microns (about a four-thousandth of an inch) without having to impose very high accuracies on the machining processes.

Fifty hoppers contain balls of different sizes. The machine measures the diameters of an inner and outer race, selects the correct ball size and feeds in balls from the appropriate hopper. Mechanical "hands" press the separators into place and the bearing is completed. Another automatic inspection follows, and then the bearings are greased, wrapped, packed and stacked for dispatch.

The planned output is 900,000 ball-bearings and 600,000 roller bearings a year, in four sizes each, from about a hundred and sixty workers. I was most favourably impressed with working conditions. Most of the machinery was totally covered in, so that the atmosphere was remarkably clean. And, as one would expect in a highly automatic plant, work went on at a leisurely pace. The workers were engaged simply in watching the machines' performance and occasionally making adjustments. They must be prepared, of course, to act rapidly and skilfully when a breakdown occurs, but I did not witness anything of that sort.

I very much regretted that I could not visit the supreme example of Soviet automation, the piston plant described in my former article. It has now been moved to a factory on the Volga, well beyond my range of travel. There is some compensation in the fact that a recent booklet, *A Soviet Automatic Plant* by A. Erivansky (Moscow, Foreign Languages Publishing House, 1955), gives a fuller description than has hitherto been available in English of the machinery, of the development work that produced it, and of working conditions on it. Any reader interested can use this book to correct several minor mistakes in my previous description. Some details are also given of a second similar line which incorporates some improvements.

I believe that this piston factory—its production cycle starts with aluminium ingots and ends with fully finished car pistons, produced at a rate of 3500 per 24-hour day under the care of nine men—is the nearest approach that has yet been made to the automatic factory. And the new ball-bearings shop must be well in the running for second place.

The apparently topsy-turvy policy of building the complex piston plant, which started work in 1950, while still very inadequately equipped with transfer machines has, in fact, got a rational explanation. It was recognised that a badly war-wounded industry could not spare resources for large-scale automation. So it was decided to go all out for experience. The project of automatic piston manufacture was chosen because it would involve experience in automating practically every basic type of production engineering process. The research engineers at the Moscow Research Institute which created this plant are confident that they now have the know-how. And as a result of an immense reconstruction effort the country now has sufficient resources to begin introducing automation widely. Production of automatic machinery in two machine-tool building factories associated with the Institute, was planned to be four times as much in the second half of 1955 as in the whole of 1954. It will be very interesting to see what the next five years produce!

ELECTRICITY FROM THE ATOM

J. J. POLLING, B.Sc.

All forms of energy are interchangeable, according to the laws of thermodynamics. So the direct conversion of atomic into electrical energy is theoretically possible. If this could be realised in practice the nuclear power plants at present under construction might well become obsolete.

What is atomic energy? It is the kinetic energy of fast particles (such as electrons, neutrons and helium nuclei) together with high-frequency radiant energy (gamma radiation) expelled from an erupting nucleus. The "conventional" method of utilising these energies for power production is to allow them to generate heat in surrounding material by simple collision, and to use this heat to raise steam to drive electric turbines in the traditional manner.

It is natural that efforts should have been made to simplify this chain of energy transformations, and to obtain electricity in a more elegant fashion. The last few years have seen the appearance of many devices capable of producing power more directly. The inventions described in this article are to be regarded as first steps in that direction: they are little more than ingenious toys, but like the frog's legs experiments of Galvani, or the magnetic experiments of Gilbert, they illustrate principles which may have far-reaching effects in years to come. None of these devices has been operated inside a nuclear reactor; all of them derive their power from radioactive materials, although there is no reason why some of them should not be designed to make use of the neutron flux of a pile.

MOSELEY'S EXPERIMENT

This story starts in 1900 when P. Curie and Mme M. P. Curie detected a potential built up by the emission of negatively charged particles from radium. This was investigated in 1903 by the Hon. R. J. Strutt who enclosed some radium in a thin-walled glass vessel and was able to charge a gold-leaf electroscope. But these experiments were made purely to investigate the electrical nature of radioactive emission, and the first conscious attempt to extract power from radioactivity was made by H. G. J. Moseley (of x-ray spectrometer fame) in 1913. He conceived the idea of collecting the beta particles emitted from radon, in the hope of generating voltages high enough to determine their energies His apparatus incorporated a simple form of attracted-disc electrometer. He enclosed the radon in a thin, silvered, quartz sphere mounted on a quartz rod at the centre of an evacuated glass bulb, silvered on the inside, as in Fig. 1. The potential built up inside the sphere was about 150 kilovolts, and a constant potential of over 100 kilovolts was maintained for three weeks.

With the growth of atomic science since then a much greater range of radioactive sources has become available. Important examples of these are polonium-210, which emits alpha particles; the "mother-daughter" pair,* strontium-yttrium-90, which emit beta particles, and hydrogen-3 (or tritium) which also emits beta particles. Cobalt-60 is an important source of gamma radiation.

In 1945 the Russians I. A. Lobanev and A. P. Beliakov constructed a direct-charging machine which produced a current of about 10^{-9} ampere; unfortunately, little is known about this apparatus. In the same year P. H. Miller, in the U.S.A., proposed the use of polonium-210 in a Moseley-type apparatus, and estimated that a current of 25 microamperes could be produced from 1 gram of polonium. An alpha source, however, has a high self-absorption, that is to say an alpha particle originating in the body of the material is absorbed before it reaches the surface, and this results in a serious loss of efficiency. Because of this E. G. Linder and S. M. Christian thought it would be wise to return to Moseley's original idea of using a beta-emitting source, and in 1952 published an account of a generator built on the Moseley principle. A diagram is shown in Fig. 2.

The radioactive source is in the form of a thin film of strontium and yttrium nitrates deposited on the inside of a thin nickel-foil cylinder which is suspended from a copper sphere by means of a metal rod. The sphere is supported on a quartz cylinder which rests on a hollow, earthed, copper vessel. The whole apparatus is evacuated so that the beta particles can pass easily from the source to the copper vessel without a leakage current flowing in the opposite direction. The effect of the loss of negative charges is to raise the copper sphere to a high positive potential, of the order of 365 kilovolts. In such a device the current generated (which is of the order of 10^{-9} ampere) is limited to the total electrical charge on the beta particles emitted from the source

* Strontium-90 decays with the emission of a beta particle into yttrium-90 which is itself a beta emitter.

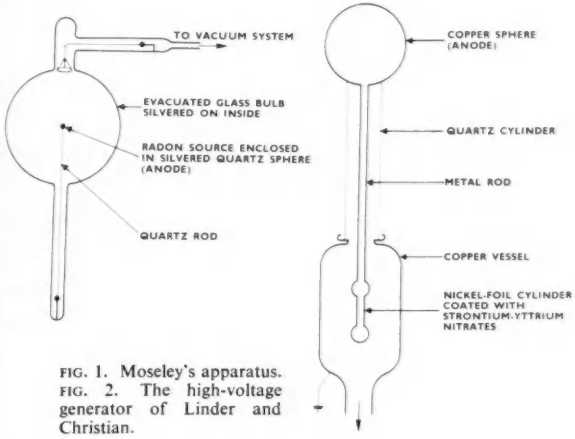

FIG. 1. Moseley's apparatus.
FIG. 2. The high-voltage generator of Linder and Christian.

per second, and this can never be very great except with the use of prohibitively high activities. Linder and Christian have suggested that there may be future commercial possibilities in their apparatus when the cost of the isotopes is reduced, but it seems unlikely that the cost could ever compete with orthodox high-voltage generators. The apparatus is simple and robust, and has excellent stability. In its present form the easily absorbed beta radiation presents no health hazard, even without shielding, but if higher activities are used to produce more practicable currents the gamma rays arising from the absorption of the fast beta particles will become increasingly dangerous, necessitating heavy lead shielding.

The next development of direct-charging devices came in 1953 when P. Rappaport and E. G. Linder described a more compact apparatus using a solid insulator to replace the vacuum, as shown in Fig. 3. A thin sheet of insulator separates a layer of radioactive salt from a metal plate; beta rays from the source have sufficient energy to pass through the insulator and charge up the metal plate, but the insulator prevents a flow of current in the opposite direction. The choice of material is a compromise between its electrical insulation and its power of absorbing beta rays. The most efficient material was found to be polystyrene, which has the added advantage of being more resistant to radiation damage than the other insulators investigated. The potential obtained was 10 kilovolts and the apparatus occupied a space of only one cubic centimetre. Also in 1953, J. H. Coleman described cells of this type that are actually being produced for the commercial market. Charged with strontium-yttrium-90 and provided with a polystyrene insulator, an aluminium collector and lead shielding, the device is 1 cubic inch in volume and generates a potential of 7 kilovolts and a short-circuit current of 4×10^{-11} ampere. This represents an efficiency of 33%. The only limiting factor to the shelf life is the radiation damage caused to the polystyrene; it has been estimated that a cell containing a 10-millicurie source will last approximately twenty-five years.

ATOMIC ENERGY AND SEMICONDUCTORS

All these direct-charging cells have the disadvantage that they can utilise only charged radiation—e.g. alpha and beta particles; uncharged radiation such as gamma rays and neutrons has no effect on them.

With the development of semiconductors entirely new techniques became possible. Semiconductors fill an intermediate role between metals and insulators, and are made from substances which in the pure state are non-conductors by the deliberate introduction of foreign atoms called "impurities". The pure substance cannot conduct electricity because the electrons are bound too tightly to their parent atoms, and the energy required for them to break free is prohibitively high. The foreign atoms added to the atomic lattice can either donate electrons to, or absorb electrons from, the lattice. In the former case it is the excess electrons which conduct electricity and the semiconductor is said to be "*n*-type"; in the latter case the absorption of electrons leaves "holes" behind which act like positive charges, and can migrate by virtue of other electrons jumping into the vacancies in succession, and a semiconductor material is made *n*-type and the other half *p*-type the impurities also act as "stepping-stones" to enable the bound electrons to attain their freedom with less energy. When a bound electron escapes from the influence of its atom and leaves a hole behind, the phenomenon is described as the formation of an "electron-hole pair".

Semiconductors have unique properties. When one is placed in contact with a metal the interface acts as a rectifier, that is to say, it allows electrons to pass in one direction only. Similarly, if one half of a block of material is made *n*-type and the other half *p*-type the junction between the two regions is also a rectifier. Such "*p-n* junctions" can be made wafer-thin and are becoming important in electronical engineering.

In 1954 Rappaport described the successful conversion of radioactive energy into electrical energy by means of *p-n* junctions. The semiconductors used in his experiments were wafers of either germanium or silicon. When such wafers are bombarded with ionising radiation, the fast primary particles plough straight through the cloud of lattice electrons, colliding with a great number of them. The collision imparts enough energy to the struck electrons to free them from their parent atoms, thus forming electron-hole pairs. If this occurs in the neighbourhood of the rectifying junction the electrons and holes are separated, the negative carriers to one side and the positive carriers to the other, and a potential is built up across the junction. Rappaport shows that for one primary energetic particle some 200,000 low-energy secondary electrons are produced. In his own experiments he used a 50-millicurie source of strontium-yttrium-90.

With germanium he obtained an open-circuit potential of 30 millivolts and a short-circuit current of 20 microamperes, while with silicon the voltage was 250 millivolts and the current 10 microamperes. These figures represent efficiencies of less than 2% but the efficiency could be considerably increased. In contrast to the direct-charging methods a high absorption is advantageous because it permits the formation of the maximum number of electron-hole pairs in the minimum distance, in the region of the junction. A semiconductor cell made by Rappaport has been used to provide the power for a transistor audio-oscillator.

Later in the same year (1954) D. M. Chapin, G. L. Pearson and C. S. Fuller reported the successful use of a silicon junction to convert solar radiation into electrical energy. The principle is similar to that of the radioactive cell, except that the ionisation is produced by photons instead of by radioactive particles. It has been reported recently that the solar battery has achieved an efficiency of 11% which is about the same as the efficiency of steam and internal-combustion engines, and far exceeds that of orthodox photo-electric devices, which have seldom reached 1%. The theoretical limit to the efficiency of the solar battery is 22%.

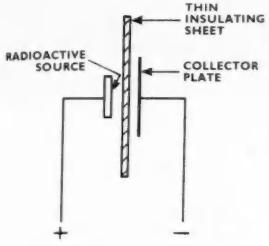

FIG. 3. Direct-charging device with solid dielectric in place of vacuum.

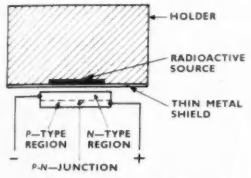

FIG. 4. Experimental investigation of the effect of beta-particle bombardment of *p-n* junctions.

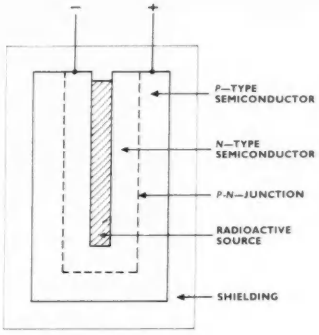

FIG. 5. A more efficient design for a *p-n* junction atomic battery.

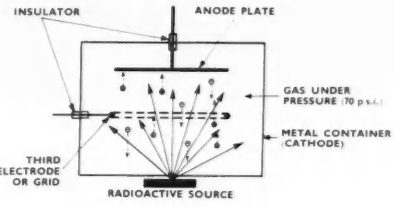

FIG. 6. Ohmart's contact-potential type of battery.

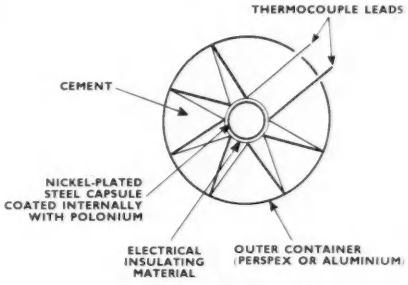

FIG. 7. Diagram of a thermocouple battery.

Also in 1954, W. G. Pfann and W. van Roosbroeck reported the independent development of a device using the same principle as Rappaport's, and likewise employing either germanium or silicon. The experimental apparatus is shown in Fig. 4. Fifty millicuries of strontium-yttrium-90 are used in the form of carbonates deposited as a thin circular layer 5 millimetres in diameter and held in place by a thin metal shield. The power of the silicon cell is 0·23 microwatt and that of the germanium cell is 0·0033 microwatt, corresponding to efficiencies of 2% and 0·021% respectively. The higher efficiency of the silicon is assumed to be due to the higher resistance of the silicon *p-n* junction. Pfann and van Roosbroeck suggest that the arrangement shown schematically in Fig. 5 would be better, for here the source is completely surrounded by the junction.

PHOTOELECTRIC DEVICE

An entirely novel method of generating electricity was proposed by A. W. Faulkner in 1951. The radioactive particles are allowed to excite luminosity in a phosphor, and this light in turn actuates a photoelectric cell. The efficiency of such an arrangement, however, would always be limited by the low efficiency of the photocell.

P. E. Ohmart, following earlier work by Lord Kelvin and J. B. Kramer, has made another contribution to this interesting field. In 1951 he described a low-voltage cell in which two electrodes of dissimilar metals are enclosed in a gas-filled bulb. A potential difference is automatically established between them as in the ordinary chemical battery, and if the gas is ionised by radiation a current flows. The open-circuit voltage depends only upon the metals used for the electrodes, while the current depends on the rate of ionisation, and in the cell described is 5×10^{-11} ampere. It has been found that the electrode metals can be placed in a sequence like the electrochemical series. The voltages generated are small (of the order of 1 volt) so Ohmart has proposed the use of the cell not as a source of power but as a radiation monitor for atomic research. Recently he has developed the cell further, by adding a third electrode, or grid, between the other two, as shown in Fig. 6. A voltage applied to the grid produces a variation in the output of the cell, as in the thermionic valve. He has also experimented with replacing the gas with a semiconductor, in which case the cell operates as a self-powered transistor.

Yet another method is due to K. C. Jordan and J. H. Birden. In their invention, described in 1954, the heat generated by the absorption of alpha particles from polonium-210 is used to energise a series of thermocouples. They calculate that a sphere 0·1 inch in diameter containing 350 curies of polonium if suspended in vacuo would attain a temperature of 2200°C. In practice they deposit some polonium (about 100 curies) on the inner surface of a nickel-plated steel capsule thermally insulated from an outer container. The hot junctions of thermocouples are connected to the capsule (but electrically insulated from it) and the cold junctions are connected to the outer container, the thermocouples being in series as shown in Fig. 7. Jordon and Birden made two cells. The first employed seven junctions and developed a power of 1·8 milliwatts; the second employed forty junctions and developed 9·4 milliwatts. A general view of typical cells is shown in Fig. 8. The advantages which these cells have over

FIG. 8. The appearance and internal wiring of a typical thermocouple battery developed by the Mound Laboratory of Monsanto Chemical Co.

orthodox chemical batteries are long shelf-life and insensitivity to changes in temperature.

It will be appreciated that while these devices are imaginative and full of possibilities for future research they do not provide a means of generating practicable quantities of electricity. Furthermore they rely upon supplies of radioactive by-products rather than upon the nuclear reactor itself. With the exception of the direct-charging techniques the efficiencies are low and the materials from which the batteries are constructed suffer from radiation damage which can seriously impair their vital properties. All the devices, if they are to generate useful amounts of power, will need extremely active sources and consequently heavy shielding, since even alpha and beta particles, though absorbed in a few millimetres of solid matter, give rise to penetrating gamma rays.

The direct-charging methods, while capable of attaining high efficiency, are limited to the use of charged-particle radiation only, and suffer from the high internal resistance of the cell, since the current flowing is equal only to the rate of flow of particles from the source.

The contact-potential method of Ohmart is sensitive to all types of radiation but still has the disadvantage of high internal impedance. Furthermore, the voltage generated is always small, and so, while there may be specialised applications in electronic apparatus, the battery does not appear to be promising as a power generator.

Both the thermocouple and phosphor methods rely upon the conversion of radioactive energy into some intermediate form, and are not, as far as power-generation is concerned, an advance upon the present technique of utilising atomic power.

This leaves the semiconductor batteries which have excited a great deal of attention. They have important advantages; all forms of radioactive energy can be used to activate them* and they do not suffer from high internal resistance. But their great disadvantage is that they are the most sensitive of all to radiation damage. The function of a semiconductor depends upon carefully controlled concentrations of impurity and upon the existence of interstitial ions. Both these factors are greatly influenced by radiation, by the production of displaced ions and the creation of vacancies in the lattice. In a nuclear reactor some of the atoms would actually undergo transmutation, and extra impurities would thereby be introduced. Methods by which this damage can be avoided or nullified have not yet been found. The study of semiconductors, however, is only in its infancy. The materials about which most is known are the elements germanium and silicon, but there are hundreds of simple compounds which can be endowed with semiconducting properties, including the oxides and sulphides of many metals.

It has been suggested that batteries powered by radioactive sources could be used to provide useful power, even in the home. However, the high cost of isotopes is a grave drawback. The present cost of strontium-yttrium-90, for example, is five shillings per millicurie and since quantities of at least 10 curies would be needed for small commercial batteries, and thousands of curies for high-voltage generators, it is obvious that the cost must be reduced a thousandfold before radioactive generators could begin to compete with orthodox methods.

The most interesting feature of the new devices lies not in their immediate practical utility but in the indication they give of possible future developments in the extraction of power from the atom.

* Strontium-yttrium-90 sources have been used in the experiments because the beta-emission is easily absorbed and no shielding is necessary at low activities.

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RATS AND MICE

THEIR NATURAL HISTORY AND ECONOMIC IMPORTANCE

R. A. DAVIS, M.Sc., D.I.C., A.R.C.S.

There are about 554 species of rats known to science, and about 130 species of mice. In Britain, fortunately, there are only three pest species which are truly commensal, that is to say dependent on man for their livelihood. These are the Common, Brown, or Norway rat (*Rattus norvegicus*), the Black, Ship, or Roof rat (*R. rattus*) and the House Mouse (*Mus musculus*).

They have been associated with man in Western Europe for many centuries, and are the subject of folklore and legend, yet we do not know precisely their countries of origin nor when they first became commensal. We take rats and mice for granted as part of our environment. Domesticated strains of two of the species have even become part of our technological culture as laboratory animals, so that we may now be regarded as to some extent dependent on them in our turn. The augurs of ancient Rome prognosticated by inspecting the entrails of birds, whereas an extra-terrestrial observer might be pardoned for supposing that we practised zoomancy, or divination by observing the actions and reactions of laboratory rats and mice. The process of adaptation and spread is still going on. Until recently, there were no rats in Alberta, Canada, but the Common rat has become established there within the last twenty years. During the last war it was introduced to the Aleutian Islands, and similarly the Ship rat was at that time introduced to some of the Pacific Islands, where previously the only rat was the small species, *Rattus exulans*. Common rats are established in the whaling stations of the Falkland Islands Dependencies, and it is no longer strange to hear of house-mice living in cold stores, even nesting within the frozen carcasses. Common rats are often associated with sewers. Recently the Ship rat has also been noticed frequenting the same habitat in Britain.

Rats of both species have been found from time to time on aircraft, where they have been known to gnaw through the electrical insulation. It is not impossible that they may have caused some unexplained air accidents. I can safely predict that within the first few years of space-travel to the moon and other planets, rats and mice will be regular uninvited fellow-travellers. At present their excursions beyond the biosphere are confined within their rôle of experimental animals, when they form the "crew" of rockets.

CENTRES OF ORIGIN

House-mice probably originated as wild species in Central Asia in what is now part of the U.S.S.R. not far from Persia, where barley and wheat have been grown from very early times. Commensal types could have originated there and spread with man and the practice of agriculture. Wild forms differ in some external characters. The distinguishing features of wild and commensal forms are summarised in Table I. Commensal forms may sometimes return to wild habitats and habits and become "feral", though it is difficult in Britain today to be sure that any house-mouse habitat is truly feral. Human activity affects in some way almost every acre of living-space on the land, so that it is hard to be sure that outdoor house-mice are not still commensal. The term "house-mouse" is almost a misnomer, for the animal occurs quite commonly on arable land, though it is by no means as common as our native wood-mice (*Apodemus sylvaticus* and *A. flavicollis*). These truly wild species sometimes enter houses and outbuildings, and are known to do considerable damage in greenhouses, but they are able to maintain populations quite independent of man.

The origin of the Ship rat, probably the first rat to arrive in Western Europe, is still a subject for study, especially if one considers the origin and status of each of the colour-forms of it known in Britain. The original home of the group was probably somewhere in S.E. Asia, perhaps in the northern part of that area. The original meanings of the English words "rat" and "mouse" are uncertain. O.E. "Mus", related to very similar Greek and Latin words, may have come from an Indo-Germanic parent word very like it, but may have been used indiscriminately for all small mouse-like mammals, including insectivores. On the other hand, the O.E. Ræt (Archbishop Aelfric's *Vocabulary*, about A.D. 1000) is of obscure origin. The word "Ratton" probably came in later with the Normans. Chaucer, in *The Pardoner's Tale*, vol. II, pp. 854–6, mentions "ratouns", in some texts "rattes". William Langland, in *The Vision of Piers the Plowman* (1377), mentions . . . "a route of ratones . . . and smale mys with hem". It is thus not possible from language evidence to be certain whether rats as distinct from mice were present in Anglo-Saxon Britain before the Conquest, or whether as generally supposed, ships of the Crusaders introduced forms of the Ship rat. It may be relevant to note that in modern Latin-American Spanish, "ratones" refers to mice as distinct from "ratas", meaning rats. There has been controversy as to the identity of the Black Death

TABLE I WILD AND COMMENSAL FORMS OF THE HOUSE MOUSE

	Wild	*Commensal*
Tail length	Always shorter than head and body length.	Tail often longer than head and body.
Fur colour	Ventral parts white, with or without dark underfur. Distinct demarcation line between colour of dorsal and ventral sides.	Darker fur, believed due to recessive genes.
Skull characters	Larger "face" and molar teeth.	Smaller "face" and molar teeth.

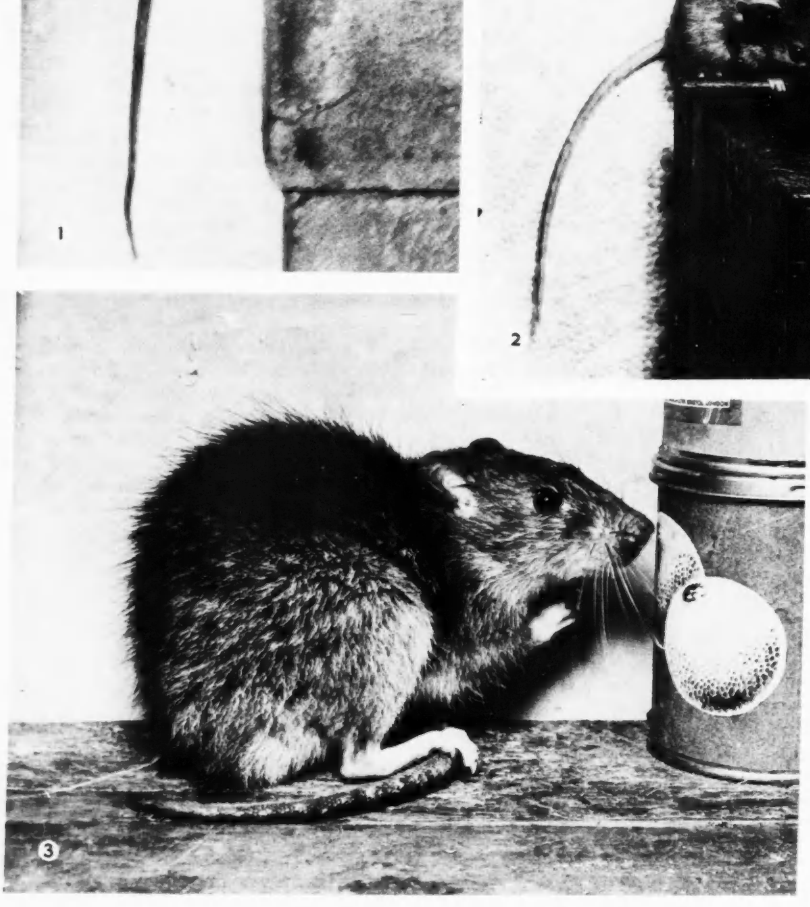
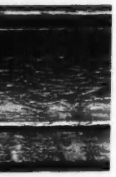


FIG. 1. SHIP RATS.
FIG. 2. HOUSE MOUSE.
FIG. 3. COMMON RAT.



RATS.
SE MOUSE.
MON RAT.

in the 14th century, but if it was the same disease known today as plague, whether bubonic or pneumonic, then rats and their ectoparasites must surely have been in Britain at that time, since no rodent found wild in Britain today is known to be a carrier of rural or "sylvatic" plague. It therefore seems certain that rats were responsible. This, with the evidence from literature, suggests that the animal was widespread by then. Earlier, Giraldus Cambrensis (1147–1223) mentions "murium majorum, qui vulgariter Rati dicuntur", which makes a definite distinction between rats and mice.

The situation is no longer obscure by the 16th century. In the reign of Elizabeth I, an "Acte for the preservacon of Grayne" fixed a price of one penny "for the heades of everie three Rattes or twelve myse". Shakespeare mentions the rat-catcher (*Romeo and Juliet*, Act iii, Sc. 1, 78), and there is no doubt of the establishment of the Ship rat by then as a common pest. It is now often called the "Black Rat" or the "Old English Black Rat", and mid-16th-century descriptions (e.g. those of Gesner and Agricola) call it very dark-coloured. The black form is usually referred to as *Rattus rattus rattus*, and is supposed to be the true commensal type of the species in Britain. Some think that the lighter-coloured "wild" forms known as *R. r. frugivorus* and *R. r. alexandrinus* appeared in Europe generally and in Britain after the First World War, and are still spreading. The species as now found in London and some other towns consists of all three colour forms, which are inter-breeding. The taxonomy and genetics of the Ship rat group is a subject not yet fully understood, and much depends on the criteria by which one chooses to define a species. The Ship rat is a smaller, lighter, species than the Common rat: the main differences between these two rats are given in Table II. The Ship rat rarely, if ever, occurs outdoors in Britain, and nowadays is mainly found in port areas and districts connected with ports by inland waterways.

The original home of the Common rat is uncertain, but it was not Norway. Probably it was in the northern part of the range of the genus, in Central Asia. It was brought to Britain probably in vessels trading from Russian ports in the early 18th century. No precise date is known. It seems to be better adapted to outdoor conditions in N. Europe than the Ship rat. In the British Isles it is found both outdoors and indoors all over the country in urban and rural areas. In S. Europe outdoor forms of Ship rat occur, but the Common rat is present also. In the tropics of S.E. Asia, the Common rat occurs only in seaport areas. The Common rat is a larger, heavier creature than the Ship rat. The two heaviest specimens of Common rat I have recorded weighed 715 grams and 725 grams, but this is unusual. Fully grown ones weighing from 200–500 grams are the largest one would expect to find in the wild state. Calculations made to illustrate the extraordinary fecundity of Common rats (see Table II) are meaningless when they neglect the very high natural mortality rates from embryo to adult. However, one may say that in theory a single pair of Common rats could in one year give rise to over 860 individuals. Even allowing for high mortality, control is obviously important.

TABLE II

CHARACTERS OF COMMON RAT AND SHIP RAT

	Common Rat	*Ship Rat*
Weight (Adult)	Up to 500 grams.	Up to 300 grams.
Tail length	Shorter than head and body.	Longer than head and body in British forms.
Ears	Short, thick, opaque, with fine hairs.	Thin, translucent, hairless, large and "bat-like".
Snout	Blunt.	Pointed.
Habits	Burrowing, but can climb.	Agile climber; very rarely burrows.
Breeding	Spring "peak"; but in ricks continues high rate in winter. 5–6 litters per year; number in litter averages 7–8, may reach 16. Gestation 21 days.	Breeds throughout year, small "peak" in autumn. Number of litters per year varies; may be 3–4. 4–9 per litter, gestation 26 days.

RAT-BORNE DISEASES

Most people are nowadays aware that plague is mainly a rat-borne disease. The rat-flea (*Xenopsylla cheopis*) can convert an epizootic among rats into a human epidemic. Both species of rat have originated human plague outbreaks, though the Ship rat is the usual host. In Britain today, other rat-borne diseases are a more real menace. For instance, leptospirosis (Weil's disease) occurs every year to some extent and yet is relatively little known. It still has a high mortality rate in patients over thirty years of age who show clinical symptoms, in spite of the discovery of antibiotics. It is to some extent an occupational disease, occurring among agricultural workers, sewer-men, fish-cleaners and coal-miners, whose work brings them in contact with damp conditions and rats. The causative organism, *Leptospira icterohaemorrhagiae*, which is excreted in rats' urine, cannot persist long in dry conditions. Up to about 40% of Common rat populations are found to be infected. The incidence of the overt symptoms in man—i.e. fever and jaundice in severe cases—is relatively low. Subclinical, and therefore not easily diagnosed, cases are possibly quite common, but some 460 cases have been recorded in a period of three to four years in Britain recently.

Trichinosis, a disease caused by a very small parasitic nematode which forms cysts in human muscles, is carried by rats and pigs; rats are an important link in the chain of transmission. Though not common, it is by no means unknown even today.

Both rats and mice carry "rat-bite fever". This consists of two separate clinical entities, one due to *Spirillum minus*, and the other due to *Actinomyces muris*. Both cause fevers, swelling of lymph glands, and muscular pains, and there may be relapses for long periods after apparent recovery. The second organism, which causes a characteristic kind of arthritis, is spread

very occasionally by rat-contaminated milk. The two infections can be spread by both rats and mice.

Rats and mice can cause a type of "food-poisoning" due to bacteria of the *Salmonella* group. Their excreta contaminate human food, and thus carry the infection. *Salmonella* occurs naturally in some populations of rats and mice, and cultures of it are still sometimes used as a method of rodent control. The type generally used is *S. enteritidis* var. *danysz*, but var. *jena* has been used also. In 1947 four human cases of salmonellosis due to the variety *jena*, were attributed to the use of "virus" to control rodents.

House-mice very occasionally cause a serious virus infection in human beings known as lymphocytic choriomeningitis. On several occasions, tularaemia, a plague-like infection normally associated with rabbits, has been contracted by the handling of mouse carcasses. It is very rarely fatal, but convalescence may take months. Mice are also responsible for infecting man with the tape-worm species *Hymenolepis nana* and *H. diminuta*; they also carry a cat tape-worm. *Favus*, a fungus disease of the skin which results in patches of baldness, is acquired directly from mice or indirectly through cats.

A rickettsial disease known as murine or endemic typhus was first described from the U.S.A. in the nineteen-twenties, and is now known to occur in a number of other countries. This is a mild disease in rats, passed from rat to rat by the rat louse (*Polyplax spinulosa*) and by the rat-flea (*Xenopsylla cheopis*) It is carried to man by the flea, infection being from rubbing the faeces of the flea into skin, and not from the flea-bite. It is milder and less often fatal than epidemic typhus.

Scrub typhus (also known as Tsutsugamushi disease or mite typhus) is another rickettsial disease, the infective agent being *Rickettsia tsutsugamushi* (syn. *R. orientalis*). The rickettsiae occur naturally in the tissue cells of certain mites, to which they do no apparent harm, and temporarily invade the tissues of a number of animal and bird hosts, causing mild symptoms or none at all. Rats in S.E. Asia are hosts of these mites, particularly in certain types of terrain such as man-made waste land. After a mite bites a human the incubation period lasts about twelve days. The disease is a serious one with a mortality of 5–15%, and it caused serious casualties in the last war in Assam and Burma. It occurs over the whole Oriental region, and extends into Australasia.

Another rat-mite which attacks man, *Bdellonyssus bacoti*, was first recorded in Britain in 1943 by Whittick, after having been first recorded in the U.S.A. in 1920. In Britain, it is so far known to be associated with Ship rats only, but in America and Hong Kong it is also found with Common rat. The mites live in rat nests, and when the rats have left or been destroyed the mites leave and may attack man. The bites are very painful; outbreaks of this rat-mite dermatitis may cause a stoppage of work if they occur on industrial premises.

These examples of disease carried by rats and mice show the importance of rodent control for public health.

DAMAGE TO FOOD

There is, of course, also the problem of loss of and damage to food. There are no reliable data, although astronomical figures are often quoted. If the rat and mouse population of Britain were known within reasonable limits of error, one could calculate how much it would consume of various commodities, assuming each in turn to be the sole diet. This has its obvious fallacies, and in any event we have no idea how many rats and mice there are, nor to what extent they are merely scavenging. We do know from practical experience that the cost of cleaning and repacking stored foodstuffs (bagged grain for instance) fouled and damaged by rodents usually far exceeds the cost of the actual amounts eaten by them. It is usually possible to state by examining the "leavings" of rodents whether rats or mice have been responsible, at any rate when grain is concerned. Mice tend to hold a grain horizontally and gnaw the middle portion, whereas rats tend to hold it "like a banana" and chew the ends. The types of "kibbling" of the grain which result are characteristic.

However, how many people realise that flour may contain rodent hairs resulting from droppings ground up in the process of milling the grain? This has been the basis of the so-called "filth test" which originated in America some years ago and caused a furore when some British food exports were rejected on these grounds. Much has been done to improve conditions since then, but in any event the only real objection is an aesthetic one, since the baking process would kill any pathogenic organisms.

Everyday observation in warehouses, storage premises and farm buildings, reveals widespread damage by gnawing of structural materials. Any material can be successfully attacked by rats, except, perhaps, $\frac{1}{4}$-inch galvanized sheet steel, applied so as to leave no free "gnawing edge". Lead pipes and metal-sheathed electric cables have been frequently gnawed through, and there are a number of recorded cases of stoppages of machinery and interruptions of lighting as a result. Damage is sometimes done to sewers, for instance by rats burrowing between brick joints and behind the bricks. Collapse of roadways due to rat activity beneath is well known in some districts of Britain, though one would not call it a common occurrence. Gnawing by rats and mice is not necessarily associated with the search for food or water, but is part of the rodent pattern of behaviour, associated with the fact that the incisor teeth grow continuously throughout life. No doubt the phenomenon has "survival value", since it persists in these highly successful species. If the incisors become displaced so that they are not apposed, lack of wear produces the most grotesque tusk-like effects. Such monstrous individuals may eventually be unable to feed effectively, or may die from the "ingrowing" of such teeth. Though unusual, a number of such specimens are on record.

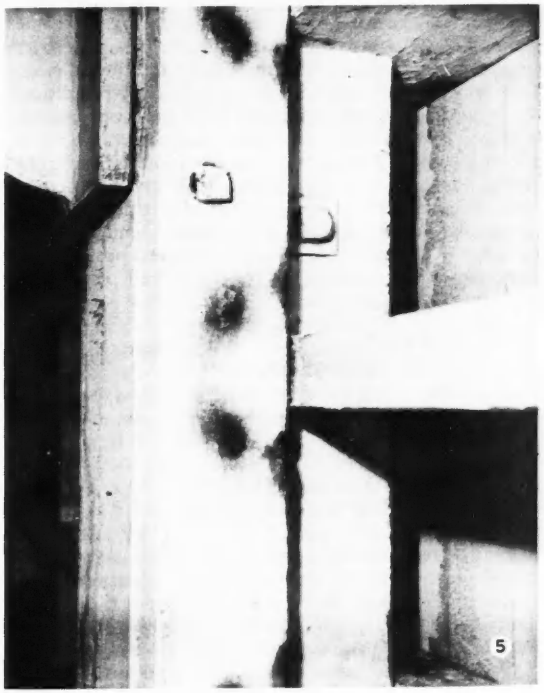


FIG. 4. Lead pipe gnawed by rats.
FIG. 5. Smears left by Ship rats.
FIG. 6. Rat-run and burrow in a field of stubble.
FIG. 7. A rat burrow under a pavement.

(These four photographs and Fig. 1 are Crown Copyright; Figs. 2 and 3 are photographs by John Markham.)

These facts make it difficult to find repellent substances that will prevent damage by gnawing, since the gnawed materials are not necessarily eaten. One cannot rely on an unpleasant taste to discourage the animals. One or two substances have been thought promising, for instance actidione, a by-product of antibiotics manufacture. This is extremely toxic, however, and could therefore have only a very limited application. The wisest counsel to give those who seek advice on repellents is probably to recommend destruction of the pests, rather than their discouragement and dispersal elsewhere. Destruction should, wherever possible, be followed by an attempt at proofing premises against re-entry.

RAT POISONS

The day of the "old-fashioned ratcatcher" is past. The methods most generally practised today are based on the scientific study of rat behaviour and depend on the resources of modern chemical technology. The special study of rats made by the Bureau of Animal Population put our knowledge on a sound basis. Methods of control were recommended which are still in use today. It was found by watching rats in the wild state, and by laboratory observations, that they react in a definite manner to a new source of food. On first discovering it, they either avoid it altogether, and continue feeding at the previous sources, or they eat only a small amount. On succeeding nights, the amount eaten progressively increases until a maximum is reached, when they feed confidently. A similar reaction is observed if any new object, such as a bait-container, is placed in a regular rat-run. This type of behaviour has been called "new object reaction", in order to avoid the anthropomorphism implicit in such statements as "the rat is highly suspicious". It was also found that over a period of a few days, rats could be "trained" to feed progressively earlier until most of their feeding is concentrated into a single meal early in the night, or even soon after the bait is put down. The number of mouthfuls taken in a unit of time can also be shown to increase. Thus when poisoned bait is laid after a few nights, a lethal dose will be eaten before rats can notice any unpleasant symptoms. Sub-lethally poisoned survivors will not usually accept the same poison again within some months, nor probably the same bait. This phenomenon is usually known as "shyness". In this instance it was not possible to find a term entirely without human connotations. It can be seen from all this that the time-honoured method of "direct poisoning" is likely to be unreliable. Laying a poisoned bait on one day without pre-baiting, and perhaps even without knowledge of which baits and poisons have been last used on the rat colony, rarely gives a high percentage kill. The acute poisons in common use include zinc phosphide, arsenious oxide, alpha-naphthyl-thiourea (antu) and sometimes red squill preparations. Zinc phosphide is a grey-black substance with a strong smell when damp, due to very slow partial decomposition, but it so happens that rats are not sufficiently affected by this property to make it unpalatable, when it is used with pre-baiting. Arsenious oxide is best used in finely powdered grades rather than coarse. Antu was first discovered "accidentally" through work on taste inheritance. A related substance was placed on the tongues of experimental rats, a number of which then died, to the surprise of the investigators. It is a relatively efficient poison against Common rat, but useless against Ship rat. Red squill is a plant product, and like many drugs of vegetable origin is of variable toxicity. It used to be supposed that one could rely upon its emetic quality for the protection of the farm and domestic animals, but R. J. Fitzpatrick showed in 1952 that this protection could not safely be assumed. It is, however, unpalatable to all these animals. It is preferable to use baits of such a texture that rats are unlikely to carry away fragments of poisoned food. Sausage rusk (a "filler" used in sausage manufacture) and oatmeal meet this need.

When using acute poisons, farm and domestic animals must be prevented from eating the baits. One can use bait-containers designed so that animals other than rats cannot reach the bait. The simplest is perhaps an ordinary agricultural drainpipe, with one end blocked, partially buried in earth near rat-runs. In tropical countries bamboo sections have been used instead. There are also special boxes into which only rats can gain access to be placed over rat-runs against the walls of buildings. Such containers have the disadvantage that rats take several days to get used to them. Sometimes it is possible to place bait in rat-holes in buildings, hollow walls, under floors, or in burrows in the open. This has the advantage of often intercepting rats between their living quarters and their normal food. When burrows are baited, pre-baiting need be done on the first and third days only, the poisoning on the fifth day. It is advisable, with the pre-baiting method, to double the amount of poison bait at places where pre-bait has been completely eaten, to allow for the possibility of "late-comer" rats.

Whatever system is used, it is important to try to remove residues of uneaten poison bait. It sometimes happens that is cannot be completely removed, for example, from hollow walls. Some rats may then take a sub-lethal dose and become poison-shy. It is therefore necessary to keep records of the kinds of baits and poisons used, so that in successive servicing, baits and poisons may be alternated. The degree of "success" achieved by a poison campaign can be estimated by baiting afterwards with plain baits, and by observing whether any filled-in holes are re-opened.

From time to time it has been thought, especially in America, that a sufficiently toxic and rapidly fatal poison could eliminate the need for pre-baiting, since the ingestion of even a trace of bait could in theory be fatal. Shyness of survivors would then be unlikely. Such a poison would, of course, be extremely dangerous. Sodium fluoracetate, marketed in America as "1080", is extremely toxic and is used as a rodenticide. There is, however, no real evidence that it eliminates the need for pre-baiting, and there is some evidence of shyness. On the other hand, it is a useful poison wherever there can

be adequate supervision to render it safe in practice. It may be doubted whether it could ever be widely used in Britain. It is interesting to note that a fluoracetate occurs in certain African plants of the genus *Dichapetalum*, the fruits of which have long been known as poison for man and rodents in West Africa. A similar plant poison causes cattle deaths in South Africa

WARFARIN

Efficient as some of these methods are, they involve much time and labour, and present a risk to other animals. A new line of approach began in 1947, when J. A. O'Connor suggested that the blood anti-coagulant called dicoumarol should be used as a rodenticide. It was thought that it would not give rats symptoms such as deter them from taking lethal doses of acute poisons (thus eliminating the need for pre-baiting) and that it might be rat-specific in the small dosages needed. Later work showed that rats could develop a shyness towards dicoumarol. However, K. P. Link, of the Wisconsin Alumni Research Foundation in America, developed the related substance now aptly known as Warfarin. This has proved, since 1950, a rodenticide of world-wide success, from Britain to Hong Kong and from St. Helena to the Antipodes. It does eliminate the need for pre-baiting, and is used in very low concentrations—0·005% for Common rats, 0·025% for Ship rats and house-mice. This lessens the chances of poisoning other animals. Nevertheless, a note of warning is necessary. If pigs, especially young pigs, have access to baits, they may die, and a number of accidents have been reported. Dogs have also been killed by warfarin. It is important to restrict access to baits, as with all other poisons. Domestic poultry are exceptional, in that it is extremely difficult to kill them with warfarin, even experimentally, and the practical risk is negligible. Anti-coagulants can also be used in plain mineral dusts, laid in places where rodents may run over them; they ingest fatal doses by their routine cleaning of their fur. This method sometimes works well with Common rats, but is unreliable with Ship rats and house-mice, perhaps because of the less predictable behaviour of the last two species. There are now a number of other anti-coagulants known as rodenticides apart from warfarin.

GASSING

Where there is an outdoor colony of Common rats, with burrows away from buildings and in consolidated soil, gassing by means of the commercial powder that liberates cyanide gas gives good results. This requires the labour of filling-in holes and re-gassing daily until no more holes are re-opened, and it is really only ancillary to other methods. Sometimes it is possible, for instance in ships and large warehouse stowages, to fumigate rodents with hydrogen cyanide gas, in a sealed space or under gas-proof sheeting material. This method is a highly skilled specialised job, and requires expert supervision.

Trapping, by means of treadle-type "breakback" traps, is not a method of first choice except to clear a very small residual infestation, and requires a large number of traps relative to the population, set across runways at right angles. Occasionally, it may be useful as a "temporary proofing" measure, to prevent re-invasion by rodents. It can deal with some mouse infestations, if a very large number of traps are used relative to the numbers of mice.

In decreasing order of efficacy, and in increasing order of venerableness, we reach the method of apostrophising the pest in rhyme (Shakespeare, *As You Like It*, Act iii, Sc. 2, 165) or of the leaving of written threats and adjurations in the fields (Frazer, *The Golden Bough*, vol. II, p. 424). This is not true of all old methods, nevertheless. "The harmless, necessary cat" was shown by Elton to have a real value in farm buildings already cleared of rats by other means, in preventing re-invasion by rats for considerable periods. The cats by themselves, however, could not clear farm infestations, but merely preyed upon continuing colonies. It is likely that the same would apply to the ordinary household, so that a cat or two may act as "proofing" against an invasion.

We might expect such animals as rats, which have come to occupy so distinct a place in the world of men, to possess peculiar distinctions. And so it is, for they show the almost unique phenomenon of the fluorescence of their hairs under ultra-violet light. Fungus-infected human or animal hairs, the hairs and skin of the Australasian mammal (*Trichosurus vulpecula*) and the fur of the American weasel, are probably the only other examples. Such a property has a limited application in the diagnosis of contamination of foodstuffs.

Rats and mice have not always been with mankind as commensals. However, it is only by continuing study that we may hope eventually to be rid of them. The alternative I have predicted at the beginning of this article.

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These papers deal with various aspects of the Biology and Distribution of the Ship rat:

Davis, R. A., "Occurrence of the Black Rat in sewers in Britain", *Nature*, 1955, vol. 175, p. 641.

Watson, J. S., "Some Observations on the reproduction of *Rattus rattus*, L.", *Proc. Zool. Soc. Lond.*, 1950, vol. 120, pp. 1–12.

Matheson, C., "A survey of the status of *R. rattus* and its sub-species in sea-ports of Gt. Britain and Ireland", *Journal of Animal Ecology*, 1939, vol. 8, pp. 76–93.

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DIOSGENIN AND THE NEW SYNTHESIS OF CORTISONE

JOHN WM. ALBANS, B.Sc., F.R.I.C.
Boots Pure Drug Co. Ltd., Nottingham

Places with names such as Whiskeyspruit, Long Tom Pass, Devil's Knuckles, Old Coach Road and Hell's Staircase are more suggestive of "Western" films than of steroid chemistry. They are, however, landmarks on a new highway in the Eastern Transvaal—names which recall memories of the early gold pioneers and of an almost-forgotten period of the South African War. The road leaves the warm and scented bushveld at Sabie, on the edge of the Kruger National Park, from where it winds through vast plantations of trees and round a seemingly endless series of hairpin bends, cut through the solid rock, to the bleak, boulder-strewn moorland which surrounds Mount Anderson. Here the road reaches a height of 7050 feet above sea-level, and then gently drops down to the small town of Lydenburg, nestling in a warm valley to the west.

The interest in this part of South Africa is due to the fact that concurrently with the commercial production of cortisone from bile-acids, there has been a world-wide search for other naturally occurring substances as starting materials. The main emphasis has been on the more abundant plant steroids, particularly those which carry an oxygen atom or hydroxyl group at C12, as this facilitates the introduction of similar radicals at the C11 position. In addition the presence of a suitable side chain at C17 is an added advantage.

The most common steroids which fulfil these conditions are hecogenin obtained from sisal waste (*Agave sisalana*) and diosgenin from various members of the yam family (Dioscoreaceae). It is around Lydenburg that the unusual succulent plant *Testudinaria sylvatica*, from which diosgenin can be obtained, is found. This plant is variously known as Tortoise plant, Schildpad and Elephant's Foot, although the latter name is more generally applied to *T. elephantipes* which is very common in various districts of Cape Province. These names very accurately describe the size and outward appearance of the roots (Fig. 3).

The family Dioscoreaceae is widely distributed throughout South Africa, and the two genera—*Dioscorea* and *Testudinaria*—differ somewhat in the nature of their tubers. The former have large, fleshy, subterranean roots, while the various species of *Testudinaria* have large firm roots which are partly exposed. *T. sylvatica* grows in pockets of soil in the rocky ravines or kloofs, and during the wet season it bears slender vine-like foliage which clings to the small bushes that constitute the main form of vegetation in this area (Fig. 2). The foliage dies after the seeds ripen, and during the dry season the dead foliage gives the only clue to the existence of individual plants. There appears to be no other practical use for the plant but, to prevent its eradication, the South African Board of Flora and Fauna have taken steps to protect it, and the collection of tubers is controlled. Those below a minimum size may not be used.

The need to find a Commonwealth source of hecogenin and diosgenin has thus led to the development of two new industries in the African continent. Details of the process whereby hecogenin is extracted from sisal waste and converted into cortisone have already been published. The extraction of diosgenin and its use in the synthesis of cortisone follows somewhat similar lines. The factory plant at Nottingham which converts diosgenin into cortisone is shown in Fig. 1.

It is with considerable difficulty that the tubers are dug out and manhandled to sites where donkeys can be used to transport them to the rail-head. On arrival at the factory the roots which contain up to 70% water are cut up and air-dried. They are then extracted with alcohol or other suitable solvent. The dark brown solid obtained by evaporating this extract is hydrolysed by boiling with acid. This process breaks down the steroidal saponins, leaving a finely divided insoluble powder which is washed free from acid and dried. The diosgenin is then extracted by means of an organic solvent. It is not advisable to store the harvested roots for prolonged periods before processing as they soon rot to a pulpy mass, although there is no evidence that the yield of diosgenin is thereby affected.

The yields of diosgenin vary with the species, and figures as high as 4–5% have been quoted for roots from Indian and Mexican sources. It should be emphasised, however, that assays of individual roots are of doubtful value and may give a misleading idea of possible commercial yields, as considerable variations are shown by tubers collected at different seasons and even from different localities.

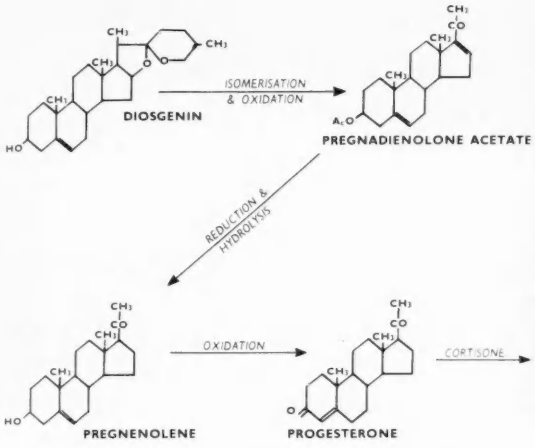
Diosgenin is produced as a white micro-crystalline powder melting at 206–9°C. It can be converted into the acetate by treating it with acetic anhydride.

For the manufacture of cortisone, diosgenin acetate is isomerised to ψ-diosgenin acetate, which can be oxidised to pregnadienolone acetate. The latter is then catalytically reduced to pregnenolone acetate, the product being hydrolysed to give pregnenolone. On oxidation, this substance is converted into progesterone, microbiological oxidation of which yields the key intermediate for cortisone, viz. 11-α-hydroxy progesterone.

READING LIST

The following four papers describe the details of the hecogenin process:

Manufacturing Chemist, 1955, vol. 26, p. 394.
Marker *et al.*, *J.A.C.S.*, 1943, vol. 65, p. 1199.
Callow, Cornforth and Spensley, *C.I.*, 1951, p. 699.
Spensley, *C.I.*, 1952, p. 426.



THE NEW SYNTHESIS OF CORTISONE BASED ON DIOSGENIN.

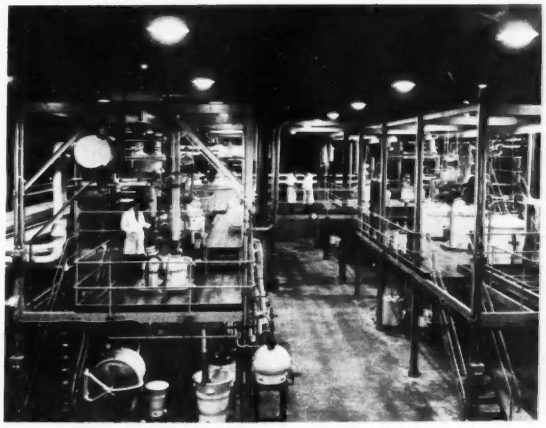
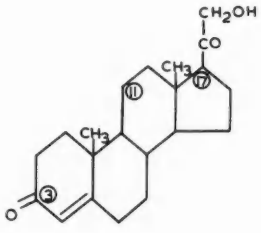


FIG. 1. Cortisone is now being produced in sufficient quantity in Britain to enable it to be used more extensively; general practitioners are now free to prescribe it. Two syntheses are being worked in Britain; in this plant at Nottingham cortisone is synthesised from diosgenin.



CHEMICAL STRUCTURE OF CORTISONE.

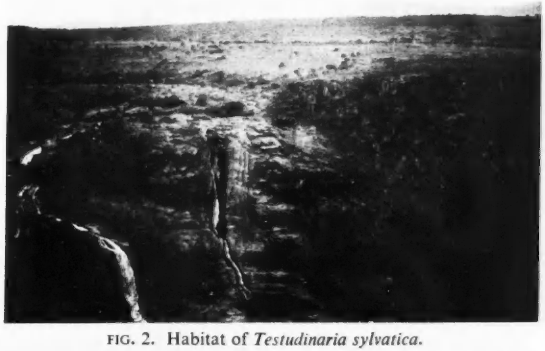
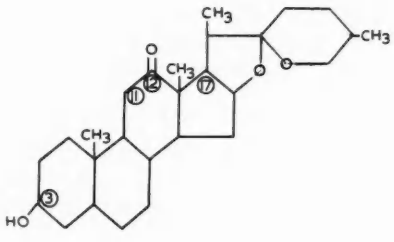


FIG. 2. Habitat of *Testudinaria sylvatica*.



CHEMICAL STRUCTURE OF HECOGENIN.

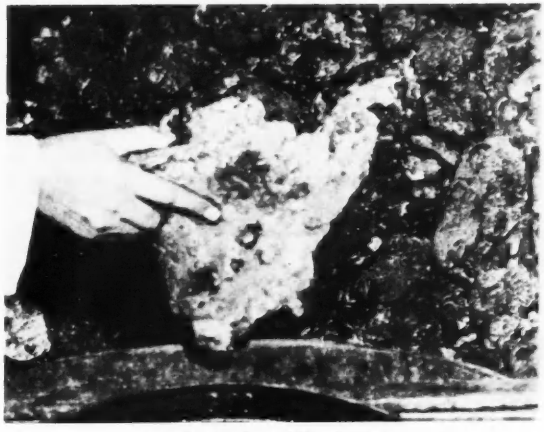


FIG. 3. A tuber of *T. sylvatica*

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THE PALOMAR SKY SURVEY

J. G. PORTER, Ph.D., B.Sc.

The enormous advances that have been made in astronomy in the last decade must be attributed very largely to the improvements in instrumental technique. Ten years ago the idea of a camera with an aperture of 4 feet and a focal ratio of *f* 2·4 would have seemed but a wild dream, yet such an instrument has been used to produce a remarkable new photographic atlas of the sky, a work which is nearly complete.

This camera (or telescope, for all modern telescopes are really giant cameras) is the 48-inch Schmidt telescope of Palomar Observatory, which was completed in 1948, and began its work early in 1949. In June of that year an agreement was reached by which a proposal to photograph the whole sky—as seen from Mount Palomar—received the joint support of the National Geographic Society of America and the California Institute of Technology. (The observatory belongs to "Caltech".) The Schmidt camera began its survey of the sky at the end of 1949.

The field of view in a giant telescope is very small, and no instrument of this kind could possibly cover the whole sky, even after many years of observation. It is therefore useful to have an instrument with a larger field of view to search for objects of interest for the big telescopes. Thus the 48-inch Schmidt is really the jackal for the 200-inch Hale telescope. It is erected on the same site on Palomar Mountain in Southern California, 60 miles north-east of San Diego, at a height of 5700 feet. The two telescopes started working together in 1949, and both soon showed their remarkable optical qualities. The 48-inch Schmidt has such superb definition that its performance is restricted only by the grain of the emulsion on the photographic plate. Stars of magnitude 20·3 are regularly photographed; this is about 600,000 times fainter than the faintest naked-eye star of magnitude 6. The telescope is of the standard Schmidt design, the Pyrex spherical mirror, 6 feet in diameter, having a correcting plate made of $\frac{3}{8}$-inch plate glass with an aperture of 50 inches. The focal length of the combination is 121 inches, giving a working focal ratio of *f* 2·44. The photographic plates which are used are 14 inches square, and the scale of one degree to 2·1 inches gives a field of 6·6 degrees along the edge of the plate, so that each plate covers 44 square degrees.

The NGS-Palomar Sky Survey will provide an atlas, not a catalogue. The primary purpose is to show as much of space as possible, affording material for study for the giant telescopes, and a wealth of physical and statistical information about the universe. Measurements of position (which ultimately depend on an accurate knowledge of the exact position of the centre of each plate) are of secondary importance. The whole sky, from the pole down to about 27 degrees south of the equator, will be covered by 879 fields, each overlapping the next by at least half a degree. Each of these fields is photographed twice, once in blue light, and then immediately afterwards in red light, using a red filter. The resulting plates (negatives) are printed (as positives) on another plate which is stored. The atlas is made from the original plates as negative prints.

The quality of the plates has been given particular attention, and they are rejected without hesitation if they show any defect due to irregularities in the emulsion, or if the sky was insufficiently transparent, or the star images poor. Since the plates are taken in pairs, the rejection of one plate automatically rejects both, so that many parts of the sky have been photographed more than once. Nevertheless, great progress has been made with this work, although it has taken longer than was first estimated. In the first year of the survey, 90 pairs of plates were available, and these had already shown the existence of many new objects. In the session 1954–5 no less than 331 pairs of plates were obtained, of which 243 were acceptable; at the time of this report 803 out of the 879 pairs had been made, and the winter of 1956 should see the task complete. The survey has already revealed many new globular clusters, more than seventy new planetary nebulae, and large numbers of *clusters* of galaxies within the estimated boundary of 300 million light-years. In addition, a number of more familiar objects such as comets and minor planets are constantly being reported.

It is interesting to compare this survey with similar experiments made in the past. The Astrographic Catalogue (Carte du Ciel), which was first conceived in 1887, aimed at positional accuracy, eighteen observatories in different countries co-operating by photographing 1200 regions of the sky each. The instruments used are of 13·5-inch aperture, 11·2 feet focal length. This work is not yet complete, although most of the observatories have published their share of the catalogue. The whole sky has been photographed repeatedly by the Harvard astronomers both from Cambridge, Mass., and also from Arequipa, Peru. The Bruce telescope which was used at the latter station gives a good proportion of stars of magnitude 18 after a three-hour exposure.

The Franklin-Adams star charts, with which all astronomers are familiar, were made at the beginning of this century by an English amateur, who photographed the whole sky from stations in England and South Africa, using a fine lens of 10-inch aperture working at *f* 4·5.

In contrast to these long exposures, the times for the blue plates with the 48-inch Schmidt are 10–15 minutes, and 45–60 minutes for the red ones; yet in spite of these short exposures the magnitude limit on the blue plates is estimated at 21·1. No doubt the statisticians will one day tell us how many millions of stars are shown on the NGS-Palomar Sky Survey, but its other secrets will be eagerly unravelled by the astrophysicists. Nearly a hundred subscribers have ordered copies of the survey. At a cost in the neighbourhood of £700 for the 1758 photographs, they will undoubtedly feel that they have had value for money.

THE BOOKSHELF

Solar Energy Research

Edited by Farrington Daniels and John A. Duffie (*London, Thames & Hudson, 1955, 290 pp., 30s.*)

This attractive and earnestly-written book is based rather loosely on a symposium on all phases of solar energy (except in food production) that was held at Madison, Wisconsin, in September 1953. The book is not a detailed account of the proceedings but is a series of essays reporting progress, stating some theoretical grounds, and pointing out directions for needed research. One of the starting-points seems to be (using the words of Dr. Palmer C. Putnam) that "the United States and much of the free world have been living high . . . off the cream of the coal, oil, and gas reserves"; consequently the symposium discusses means for putting the sun to work harder, or more effectively, at generating energy from wind-power and heat-pumps as well as in domestic space-heating, and operating the more obvious machines such as evaporators, cookers and furnaces, besides photochemistry, thermo-electricity and *ad hoc* photosynthesis. An Indian and a Frenchman took part; though no Briton attended the gathering, Prof. Harold Heywood of Imperial College, London, has a report of his work in the book. Prof. Daniels supplies the Introduction and Conclusions; Dr. Duffie surveys U.S. patents pertaining to utilisation of solar energy.

The symposium would have been stronger if it had included some pertinent biological scrutiny, but the resulting challenge to its assumptions would have lessened the optimism. Though only a section is devoted to photosynthetic applications, the biological argument is implicit in the editorial remark that the energy in all our food and fuel comes originally from the sun through photosynthesis. To leave biological matters to engineers or physical chemists evidently leads to unsureness of aim and to the sort of basic inconsistency that is tolerable only in science fiction.

Many interesting points occur; thus, domestic use of solar water-heaters was common in California until they were all but ousted about 1930 by oil heating; E. J. Drake has ingenious ideas for using the night sky. Many of the expositions of the potentialities of apparatus for harnessing the contemporary energy of the sun are accompanied by balance-sheets or estimates of efficiency. None of these, however, appears to take account of energy needed to fabricate the equipment (and, for algal culture, to make the nutrients). Such energy of fuel and electricity would be difficult to meet from current (income) sources, but there is no second backward glance to stored energy: the possibility of making the various schemes self-sustaining is not discussed.

Granted the assumption that energy for metals, glass, plastics and plant nutrients need not be taken into account, the discussions may be called cautious and moderate. The book is a valuable source of non-biological data, and also of warning. Its chief—if involuntary—lesson seems to be that any who are tempted to hope that contemporary solar energy can relieve the pressure on fossil fuels should think again. The content of this book suggests that the fundamental assumptions need to be reviewed, and that less should be taken for granted.

HUGH NICOL

Soil Zoology

Edited by D. K. McE. Kevan (*London, Butterworths Scientific Publications, 1955, 512 pp., 55s.*)

Although most zoologists have some idea of the importance of soil animals they would probably be astonished how important they appear to be. Prof. Kubiena, expert on the soils of Europe, even goes so far as to say that "the activity of soil animals has such a decisive influence on the composition and the structure of the humus horizons that it must be considered to be the most important criterion for the definition and the classification of the different humus forms". Yet soil zoology receives comparatively little attention. As Prof. Hallsworth put it, "One almost gains the impresson . . . that to the professional soil worker, the occurrence of animals in the soil is an unfortunate accident, and one which should be ignored wherever possible. . . ." The School of Agriculture of the University of Nottingham is therefore to be congratulated on making "Soil Zoology" the subject of their Second Easter School, and the Editor, Dr. Kevan on producing this report of the proceedings so soon after the meeting.

To use the term "school" for a gathering of this sort is, surely, to overstrain its meaning. In fact, the meeting was more of a symposium, a gathering of specialists in various aspects of soil zoology, and including some of the outstanding continental workers like Profs. Kubiena of Madrid, Kühnelt of Vienna and Tischler of Kiel. However, it also tried to provide instruction "both theoretical and practical, for those working in the field who . . . hitherto have had no specialist training". The book is divided into two parts, each with about twenty-five communications. Part I is arranged in five sections: Introductory (mainly faunistic), Pedology, Ecology, Applied Aspects and Zoophagous Fungi. Outstanding in this part is the paper by Kubiena on soil fauna and humus formation, and the two by Tischler on the effect on the fauna, of agricultural practice, and soil type and vegetation; students of animal behaviour would find the latter paper of particular interest. Many of the papers deal with special groups of animals: there are papers on Nematodes, Earthworms, Enchytaeid worms, Mites, Collembola, Symphylids, Termites, Millipedes and Centipedes, and Fungi.

Inevitably there must be considerable unevenness in a book of this sort. The many contributors clearly have differing ideas as to how far the relative claims of the experts and the "scholars" should be catered for. Some papers are of crystal clarity and obviously directed at the beginner; others, on the other hand, would be difficult for the expert and contain factual material which even the editor of a specialist scientific journal would find it difficult to include. Nevertheless, the book will undoubtedly stimulate interest in the soil fauna and zoologists and agriculturists of all sorts will find much to interest them in it; but one can hardly take seriously the suggestion of the editor that the sixth-former would also benefit.

I am much more doubtful about Part II, devoted to Methods. The demonstration and description of techniques at such a meeting is obviously of great importance, but one wonders whether they should also have been published in their present form. Some of the techniques described are in process of development, and many have or will be more fully described elsewhere; and several techniques for doing the same sort of thing are described by different workers with no independent judgment of their relative merits. On the other hand, comparisons of various methods, like that presented by MacFayden, are of real help.

Valuable as this book is, its value would be increased by greater selection of the material published; at the moment the editor is trying to produce both a report of the proceedings of a meeting, and some sort of textbook ("not a complete textbook" is how he puts it). I feel that the former function would not have suffered and the latter have been enhanced by greater selection and unification of the material included in the section on Methods; and if the price were thereby reduced, so much the better. The inclusion of a glossary would be a great help.

C. ELLENBY

The Robot Era

By P. E. Cleator (*London, Allen and Unwin, 1955, 172 pp., 16s.*)

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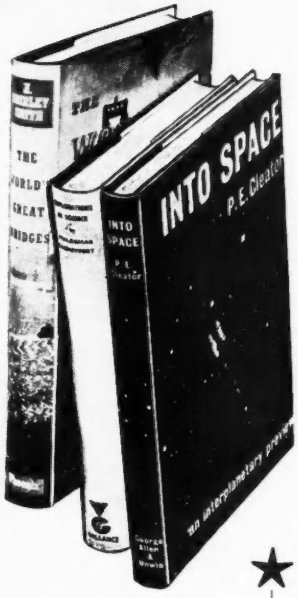

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account of the development of modern science and technology. The subject matter includes atomic energy, guided missiles, space travel, electronic computers, automatic machinery of various types and automatic factories; and he has also found room for his own views on such topics as eugenics and society, the artificial production of living matter and the possibility of "Homo sapiens" being replaced by intelligent machines.

Such a task obviously demands the most careful selection of material and conciseness of style if the thread of the book is not to be lost in a welter of facts and fancies. Although the book contains a number of excellent photographic illustrations, and although some parts are carefully written and give lucid accounts of certain scientific developments such as atomic energy and computing machines, yet in general Mr. Cleator appears to have addressed himself to his task in a mood of cheerful abandon. He has a lively, one might even say breathless, style and in places he seems to be carried away by his own verbosity. For example, it is surely unfortunate that, on the very first page of text, we should read the following description of the lever: "We can picture . . . [some primitive forebear] . . . playfully inserting one end of his improvised staff into a gap between two adjacent boulders. We can imagine his astonishment and delight at finding that his lifting powers were thereby increased no less than tenfold [why tenfold?]. And we can anticipate the solemn warning of his union leader, that such inexplicable levitation threatened the livelihood of all the members of the confederation of master weight lifters and quarry-men." One feels that such flights of the imagination go far beyond what is desirable or necessary in even a "popular" book such as this. The same may be said of the twelve cartoons of doubtful relevancy.

As a consequence of his style and choice of material the author has often been forced to oversimplify his descriptions, sometimes with misleading results. In discussing the implications of Wöhler's synthesis of urea from ammonium cyanate, for instance, he says: "This classic demonstration heralds the artificial production of living matter," without discussing either the problems this will involve or the difference between living matter and the chemicals produced by living organisms. Again, the selection of examples is not always particularly apt. The first page of the chapter "Enter The Computer" contains a description of Babbage's Difference Engine, but his Analytical Engine is not mentioned although it, and not the former, was the forerunner of the modern electronic digital computer.

After reading the book, one wonders for whom it is intended. The serious student will doubtless be irritated by the style and presentation of material. The reader without such scientific knowledge may find this a very readable book, but it is by no means certain that it will give him any real understanding of the development and consequences of the Robot Era.

H. D. TURNER

Low Temperature Physics

By L. C. Jackson (*New York, John Wiley; London, Methuen, 4th edn., 1955, 158 pp., 10s. 6d.*)

It might be thought that the remarkable dissemination of cryogenic techniques over the last ten years would make the notion of low temperature *physics* only a little less absurd than that of "room temperature" physics. In fact the conventional idea of the field has been narrowed down, so that—apart from the techniques—the main topics are now the obvious ones: liquid helium, superconductivity and certain parts of magnetism connected with adiabatic demagnetisation. It is recent work on these topics that has provided Dr. Jackson with some thirty pages of fresh material for his well-known monograph. As a result, the book is once more an excellent introduction for the research student starting work at low temperatures, as well as an intelligible survey for any trained physicist. The older parts—particularly those on techniques and specific heats, which make up nearly half the book—will still be found useful by undergraduates reading physics.

The chapter on helium has been most heavily revised and now includes the new work on film thickness and film flow together with some account of "second sound", the two-fluid model and Landau's theory. Some readers may feel that here the exposition would have been improved by a derivation—however crude—of the velocity formula for second sound. Such a device would help to give substance to the bare statements made about the "superfluid" and "normal" components of the liquid.

The work on superconductivity is to be found in the chapter on electrical conductivity, although the connexion is more etymological than logical. The main additions deal with new knowledge about the penetration depth of the magnetic field (gained from experiments on resonant cavities and thin specimens) and with the London phenomenological theory. (The symbol "H" does not mean the same here as in the earlier, thermodynamic discussion.)

The section on magnetism now includes a fuller account of the magnetic properties of rare earth ions (as disclosed by paramagnetic résonance measurements), as well as brief remarks on antiferromagnetism, the Faraday effect in paramagnetism, and nuclear alignment. There is virtually nothing on resonance techniques.

Some readers may be relieved to know that von Laue's *Theorie der Supraleitung* (listed in the references) is now available in English translation.

R. O. DAVIES

Ageing in Industry

F. Le Gros Clark and Agnes C. Dunne (*London, The Nuffield Foundation, 1955, 149 pp., 6s. (6s. 4d. post free)*

Old age in this new world of ours, the world of the Welfare State, has come under the microscope. Older members of our community are being subjected to scientific study by specialists in geriatrics, by psychologists and sociologists. In the industrial field alone, researchers, encouraged by the Ministry of Labour, are investigating the skills, abilities and aptitudes of elderly workers, and are trying to persuade employers to extend employment opportunities for them. This inquiry into Ageing in Industry adds considerably to what is known about the older worker in industry.

The authors' aim was "to determine . . . what numbers of workers are physically able to continue in their various occupations beyond their mid-sixties". Their mission was a fact-finding one. The study deals with male workers only in thirty-two selected occupations, and in each of these the authors, largely on the basis of tables of age and occupation in the Census Reports for 1921, 1931 and 1951, have followed through the years the movements of men in these listed trades. Having extracted from these reports the information they required, they subjected their facts to further test by investigating the industries statistically surveyed, and by questioning Government Departments and Trade Unions.

They established that "the capacity of men to continue beyond their mid-sixties depends mainly upon the actual jobs they have to do". As stress and responsibility varied, so did the ability of older men to do their jobs. The less the stress of the job, the greater the survival rate of older workers fit to do it. To add to the picture of working old age the authors measured the drift of older men from the occupations under survey.

The urgent responsibility for finding alternative jobs for older workers is stressed. This inquiry showed that 30–40% of men in these thirty-two occupations could not do their normal jobs beyond normal retirement age. The problem of alternative work is largely a matter for industry to grapple with, and I suggest the first step in its solution is by job analysis. Ours is an ageing population, and the two problems of employing older workers or of maintaining them in unwilling idleness will become more acute. More research of this kind and more notice of such research are needed.

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This feature is designed to provide information about new scientific instruments which have come on the market. The detailed facts in it are the responsibility of the manufacturers, being taken from literature supplied by the makers. The editor will welcome information from manufacturers about new scientific instruments they are putting on the market. As these notes are intended for the large section of our readership composed of professional scientists, etc., we depart from our customary practice and use symbols and abbreviations to the full in order to be able to convey the maximum amount of detailed information.

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Electrothermal Engineering Ltd., 270 Neville Road, London, E.7.

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Electro Methods Ltd., Caxton Way, Stevenage, Herts.

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The principle of the galvanometer amplifier is shown in Fig. 1. It consists of a taut-suspension moving-coil galvanometer rigidly attached to a second coil which is placed in an alternating magnetic field. When the second coil is parallel to the direction of the alternating field no voltage is induced in it, when it is rotated to either side of this position an alternating voltage is induced, the phase reversing as the coil passes through the zero position. In this way a direct current applied to the normal coil will be converted into an alternating voltage in the second coil.

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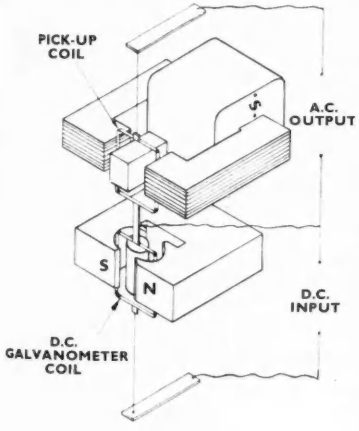

FIGURE 1

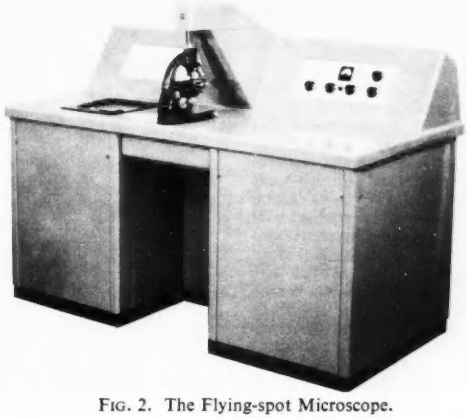

FIG. 2. The Flying-spot Microscope.

gain (r.m.s output/d.c. input) is approximately 1500. The input resistance of the coil is 40 Ω and the critical damping resistance 700 Ω; the free period is 2·8s. It is also incorporated in a sensitive d.c. microvoltmeter (No. 11340), which can replace a reflecting galvanometer or a d.c. amplifier, with good zero stability. The nanoammeter (No. 11360) will be available shortly.

W. G. Pye & Co. Ltd., Granta Works, Newmarket Road, Cambridge.

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The "Cintel" flying-spot microscope is an instrument for the display to large audiences of pictures of high definition, large magnification and low "noise" level of specimens, including live ones, normally viewed through a microscope. It combines a conventional optical microscope with a flying-spot scanner; the latter converts a two-dimensional density distribution into a varying voltage/time relationship suitable for transmission to a monitor screen.

The principle of operation is as follows: a raster on a scanning cathode-ray tube scans a very small portion of the object on the slide, through the microscope, which is virtually being used in the reverse direction to normal, the amount of scan reduction being equal to the normal magnification of the microscope. Light passing through the slide will be modulated by it and is collected by a condenser lens and passed to a multiplier photocell. The resulting electrical signal is amplified and used to modulate a monitor cathode-ray tube the raster of which is synchronised with the original scanning raster.

The total magnification of the system is the magnification of the optical microscope × (size of scanning raster)/(size of monitor raster) = × 6400 in the standard equipment in which the optical microscope is a Baker Type 4AQ. The system has so far resolved 100,000 lines to the inch, but it is hoped to improve on this. Several external monitors may be operated from the one equipment.

Cinema-Television Ltd., Worsley Bridge Road, Lower Sydenham, London, S.E.26.

Sound Level Meter

The type 140 Sound Level Meter is a portable instrument designed to carry out a variety of acoustical measurements over a wide range of frequencies and intensities and to provide an objective method of measurement of the type standardised by the American Standards Association ("Sound Level Meters for Measurement of Noise and other Sounds", Z24.3—1944). The instrument consists of a sensitive Rochelle-salt crystal-diaphragm type microphone, an attenuator calibrated in steps of 10dB from 40–140dB, a high-gain amplifier with sub-miniature valves and components, an indicating meter reading from −6dB to +10dB, and self-contained dry batteries, together with three electrical weighting networks. These simulate the frequency response of the human ear corresponding approximately to the 40, 70 and 100 phon Fletcher and Munson equal loudness contours (*Journal of the Acoustical Society of America*, 1933, vol. 5, p. 82) for low, medium and high volume. Negative feed-back is used to stabilise the gain and improve the overall frequency response. This is practically flat between 25 c/s and 8 kc/s. The instrument will read sound levels between 24 and 140dB or if the "flat" frequency characteristic is used, the sound pressure level in decibels, is indicated. The reference level is 0·0002 dyn/cm² at 1 kc/s. The high frequency range can, in some circumstances, be extended. The equipment can also be used as a sensitive a.f. amplifier and by replacing the microphone with the special pick-up and adaptor unit, type 1404, it can be used for vibration measurements in the range 25–500 c/s.

Dawe Instruments Limited, 99 Uxbridge Road, London, W.5.

FAR AND NEAR

Atomic News

The Queen is to open the Calder Hall power station on October 17, when electricity will start flowing into the national grid.

Two new research reactors are operating at Harwell, announced the AEA on January 17. They are ZEUS, a name adopted from the initials of its title Zero Energy Uranium System and ZETR (Zero Energy Thermal Reactor).

ZEUS has been built to check the nuclear calculations on which the design of the fast reactor being built at Dounreay in the north of Scotland depends, and in many essentials it is a full-scale model of the Dounreay reactor.

A team from the Industrial Group of the AEA and the group of Harwell scientists working on ZEUS have combined and are gaining experience of the running of a fast reactor. The cylindrical core of the reactor, which is roughly 20 inches in diameter and 20 inches long, is made up of uranium, which is very highly enriched in uranium-235. Thus in ZEUS uranium is used as a fuel whereas in ZEPHYR, Harwell's first fast reactor, plutonium is the fuel employed. The core of ZEUS is surrounded by many tons of uranium in which plutonium is formed gradually as the pile runs. The reactor will operate at a very low power level, only 100 watts, so that no cooling is required although the rate of the nuclear reaction will be quite adequate for making all the necessary nuclear measurements. (The design power for the Dounreay reactor is about 60 megawatts.)

ZETR uses a nuclear fuel in solution and is intended to provide information about the quantities of fuel which will be required for large-scale reactors using such solutions. Plutonium has already been studied in this reactor; uranium-235 is being studied now and uranium-233 is to be studied later this year. Natural water is used as a solvent at present, but in the summer heavy water is to be used.

The only official and unabridged report of the proceedings of the international atomic conference held in Geneva last August is now being published in sixteen volumes. The first of this series of volumes to be published is Volume III, entitled "Power Reactors". This is a well-printed book of 400 pages with approximately 400 illustrations, and costs 54 shillings. A leaflet giving details of contents and price for the remaining fifteen volumes can be obtained from: H.M. Stationery Office, P.O. Box 569, London, S.E.1.

The Federal German Republic is due to receive a consignment of uranium-235 from the U.S.A. almost immediately. Herr Strauss, Minister for Atomic Questions, has stated that the contract with the company which is to construct a reactor at Karlsruhe will be concluded soon. The German Atomic Commission met for the first time on January 26.

France's first industrial nuclear reactor (known as G1) began to operate on January 7. This reactor has been erected at the atomic centre of Marcoule, in the Gard, where eventually there will be another industrial reactor, a plant for extracting plutonium and two electricity generators. The designed output of plutonium is 15 kilograms; this will be increased to 50 kilograms when the second pile (G2) is operating.

The Times reports the conclusion of an agreement to establish in Baghdad a joint atomic energy training centre for Baghdad pact countries. The centre will be provided with experts from Harwell.

Civil Defence in the Atomic Age

The Home Office has scrapped its original Civil Defence training pamphlet dealing with atomic bombs and replaced it with a training manual entitled *Nuclear Weapons* (H.M.S.O., price 2*s.* 6*d.*). This covers hydrogen bombs as well as fission bombs.

Estimates of the scale of damage that would result from a 10-megaton hydrogen bomb (equivalent to 10 million tons of TNT) are given right at the end of the booklet. Such a bomb "bursting at ground level is expected to produce a saucer-shaped crater about a mile in diameter. The debris from the crater would be scattered around in a ring about 2 miles in diameter and the remains of any structures in this area might consequently be buried. Severe earth movements might be caused at greater ranges and underground structures might be affected up to a few miles."

Nuclear Weapons is simply and lucidly written, and designed for the intelligent layman involved in Civil Defence preparations.

The Night Sky in March

Something not previously dealt with in these notes on the Night Sky is the occultation of stars by the moon. As our satellite revolves round the earth from west to east it is inevitable that at times it will interpose between the earth and some of the stars. At such times the light from the star which we can see at one instant is suddenly cut off by the moon's rim—the eastern rim or the rim on your left as you face the moon—and the star is said to be occulted. If you look long enough the star will reappear behind the western edge of the moon, but in the case to be described you need not look out for that. The exact times of appearance and disappearance depend upon the position of the observer, but we shall give the times in this and all subsequent cases as though the observations were made at Greenwich. Of course at other places there would be differences depending upon the latitudes and longitudes of the observer. For instance, there might be a difference of 10 minutes between the times of an occultation observed at Greenwich and Edinburgh.

On March 18 at 7h 36m 6s p.m., the star ι Tauri will be occulted. It is a faint star and only just visible to the naked eye; as the moon is new on March 12 there will be sufficient moonlight to render good observation of the stars a little difficult, so it will be better to use binoculars and keep observation of the eastern limb of the moon some time before the occultation is due. You should be able to see the star—weather permitting—as the moon in its revolution round the earth approaches it, and if you can pick it up keep it in view until it touches the moon's limb and then vanishes. There are no occultations of interest to the amateur in the next few months, but I will mention this phenomenon again later in the year.

Dealing with the planets, *Venus* sets at 21h 30m, 22h 15m and 23h on March 1, 15 and 31, respectively, and cannot be mistaken for a star as it is a very bright object shining in the western skies. *Mars* rises at 3h 50m, 3h 25m and 3h at the beginning, middle and end of the month, respectively, and has an eastward movement in Sagittarius, lying rather low for good observation. *Jupiter* is visible throughout the night and early morning hours; its slow westward motion in Leo away from Regulus is easily noticed. *Saturn* rises at 1h 10m, 0h 10m and 23h 10m on March 1, 15 and 31, respectively, and lies rather low N. of Scorpius, less bright than Antares, the brightest star in this constellation. M. DAVIDSON

Mond Nickel Fellowships

The Mond Nickel Fellowships Committee invites applications for the award of Mond Nickel Fellowships for 1956. Each fellowship will occupy one full working year. Five such fellowships, each worth £900–£1200, can be awarded. Full particulars can be obtained from: The Secretary, Mond Nickel Fellowships Committee, 4 Grosvenor Gardens, London, S.W.1. Applications have to be received by June 1956.

Scientific Essay Competitions

Larger prizes are being offered in the scientific essay competition organised by *Research* and the *Sunday Times*. A special prize is being reserved for Commonwealth scientists. Full details of the competition and conditions of entry may be obtained by sending a stamped addressed envelope (1½*d.*) to: 1956 Competition Conditions, *Research*, at 88 Kingsway, London, W.C.2.

Chinese Astronomical Clockwork

The mechanical clock, with escapement and gears, has generally been thought to have originated about A.D. 1300 in Europe. Now evidence has been brought to light which indicates that the Chinese built a clock of this kind in A.D. 1088, and perhaps as early as A.D. 725. In a lecture to the Antiquarian Horological Society, Dr. Joseph Needham, of Cambridge University, one of the authorities on ancient and medieval Chinese science and technology, described a book entitled "Outline of a New Method for Rotating an Armillary Sphere and a Celestial Globe", written by the Chinese astronomer Su Sung (A.D. 1030–1102). The book contains text and diagrams, showing in elaborate detail the mechanism of the clock, driven by a water-wheel and using an escapement and trains of gears.

Su Sung was a highly successful civil servant who held, among other offices, the post of tutor to the Emperor's sons. A curiously modern touch is the fact that his serious interest in astronomy was first aroused when he came out top with an essay on astronomy in the imperial examinations for the civil service.

The clock, which occupied a tower 30–40 feet high, was operated by a wheel on which were mounted a series of cups. As each cup filled with water and moved on, its weight tipped a lever which arrested the driving-wheel at another place. As the Chinese divided each day into 100 "quarters" as well as twelve double-hours, the time-keeping wheels were arranged to record 100ths of a day. Each time the wheels moved, figures or jacks appeared at windows to indicate the time. Simultaneously, the armillary sphere and celestial globe, which were mounted on and beneath the roof platform of the tower, rotated.

When the Jesuits came to China in the 1600's, they proudly brought with them contemporary European clocks, with escapement mechanisms operated by weights and springs. Until Dr. Needham's discovery it was thought that subsequent Chinese clocks were wholly inspired by the European models.

It is now a matter of some interest to find out whether the boot was not on the other leg. It seems possible that Marco Polo may have brought back from his travels some information on Chinese clocks. Some pictures in European manuscripts earlier than 1300, hitherto rather enigmatic, may illustrate the first Western developments of the prior Chinese tradition.

Personal Notes

PROF. H. W. MELVILLE has left Birmingham University, where he has been head of the chemistry department, to succeed SIR BEN LOCKSPEISER as secretary of the Department of Scientific and Industrial Research. Aged 47, he is an authority on polymer chemistry.

After months of negotiation, the vacancy created by Sir Edward Bullard's resignation from the directorship of the National Physical Laboratory has now been filled. His successor, announced last month, will be DR. G. B. B. M. SUTHERLAND, F.R.S., Professor of Physics and director of the Biophysics Research Centre in the University of Michigan. DR. R. L. SMITH-ROSE will continue to be acting director until Prof. Sutherland takes up the appointment, probably in September.

Prof. Sutherland, who is forty-eight, is a well-known authority on infra-red spectrum analysis. Last month we referred in a leader note to some of the obstacles which accounted for the delay in finding a successor for Sir Edward Bullard. The salary question was mentioned, and we understand that the salary which goes with the NPL directorship has now been increased.

LT.-COL. C. A. BOZMAN has been appointed Director of the Wellcome Museum of Medical Science.

PROF. P. W. RICHARDS, M.A., Sc.D., and MR. H. WARDALE have been appointed members of the National Parks Commission. Prof. Richards, whose appointment follows the resignation of Prof. R. C. McLean, is Professor of Botany at the University College of North Wales.

BRIGADIER P. B. E. ACLAND, DR. NANCY G. DAVIES and MR. W. B. YAPP have been reappointed members of the Commission.

MR. BRIAN LAIDLAW GOODLET, aged fifty-one, at present deputy chief engineer at Harwell Atomic Energy Research Establishment, has been appointed chief engineer and director of the Brush Electrical Engineering Company, Ltd., from April 1, the company announced yesterday. A South African and former Professor of Engineering at Cape Town University, Mr. Goodlet was named last year by Sir John Cockcroft, Director of the Atomic Energy Research Establishment, as one of the two men chiefly responsible for design of the first British power reactors.

Continued on p. 134

CORRESPONDENCE:

THE ESSENCE OF HOMOEOPATHY

Sir:

I have read Dr. Underwood's article "Polypharmacy to Chemotherapy" in the January issue of DISCOVERY with much interest, but was very surprised to see his erroneous comments on Homoeopathy.

Homoeopathy is a system of therapeutics based on many years of observation and experiment by Dr. Samuel Hahnemann in the 19th century, and verified by much further laboratory experiment and clinical observation since then. The basis of Homoeopathy is the *law* that any substance that can produce symptoms in a healthy person may be used successfully in the treatment of a sick person with those same symptoms. It is well known in Dermatology that one of the symptoms of chronic arsenical poisoning may be the eruption of vesicles, and yet the dermatologist may on occasions, use Arsenic in the treatment of a vesicular eruption. Again, the symptoms of acute arsenical poisoning and ptomaine poisoning are very similar: the homoeopathic physician would treat most of his food poisoning cases with arsenic—naturally in very small doses. One could, of course, multiply these instances, but space forbids.

Dr. Underwood finds it impossible to believe that the minute doses generally used by homoeopathic physicians can have any effect at all on the organism. Because a person does not believe a thing, it does not follow it cannot happen.

If Dr. Underwood would try the experiment, as so many open-minded physicians have done, he would find that these doses do have a very potent effect on the organism. Not only have we innumerable clinical proofs of this, but in the *British Homoeopathic Journal* (January 1954) is published a paper by the late Dr. W. E. Boyd of Glasgow, setting out laboratory proof of this power of homoeopathic potencies to influence biochemical and biological processes.

The homoeopathic potency does not depend for its activity on any "substance" contained in the dose administered, but on the crude substance's latent energy, which is liberated by the special method of preparation—much like what happens in the production of colloidal preparations.

A very common idea about Homoeopathy is that its essence lies in the minuteness of the dose. This is not so, as patients can be treated homoeopathically by quite appreciable doses, provided the remedy is chosen on the similarity of the symptoms of the patient to the symptom picture of the drug. In other words the basis of Homoeopathy is "Similia similibus curentur".

In choosing his remedy the homoeopathic physician does not depend solely on the physical diagnosis of his patient, but takes very prominently into account his patient's mental and emotional reactions to his environment. That is to say that to the true homoeopathist *every* medical problem is a psychosomatic problem.

Yours sincerely,

ALVA BENJAMIN,
M.B., Ch.M., F.F.Hom.

London, W.1.

FAR AND NEAR—continued

The following scientists have been given awards under the Royal Society and Nuffield Foundation Commonwealth Bursaries Scheme: Dr. A. Bose, Dr. H. B. S. Cooke, Mr. R. G. Cooke, Mr. G. C. Israel, Prof. L. C. King, Mr. A. D. McKay, Dr. K. G. McNeill, Mr. G. B. Masefield, Mr. S. Smith-White, Dr. A. M. Stephen and Mr. M. W. Tracey.

Abortifacient Drugs

Some of the substances that reduce human fertility are discussed by Sir Solly Zuckerman of Birmingham University in *Nature* (1956, vol. 177, p. 58). A number of anti-metabolites have been tested for abortifacient action after the chance discovery that aminopterin destroys the litters of mice, rats and dogs when given to pregnant animals. The most effective compound in the case of rats proved to be azaserine. He says that aminopterin has now been given in a clinical trial on twenty-six patients in whom pregnancy had to be terminated for medical reasons. In the great majority the drug acted effectively, but there were complications in the remainder.

Zuckerman comments that "the practical goal of these urgently needed researches—the discovery of a 'pill' which can be taken by mouth, and the only physiological effect of which would be that of inhibiting the development of the fertilised ovum, or of suppressing ovulation or gametogenesis at will—is so remote from realisation that at this stage no one can say how, when or even whether success will ever be achieved".

Royal Society's Antarctic Base

The advance party of the Royal Society Antarctic expedition for the International Geophysical Year, led by Surgeon Lieutenant-Commander David Dalgleish, R.N., has established a good base, at 75° 36′ south, 26° 45′ west, on the coast of Coats Land on the Weddell Sea. The motor vessel *Tottan* is now on its way back to Britain. The party it has left behind will establish a research station and begin making scientific observations.

Soil Profiles: An Atlas in Colour

The book by Prof. W. L. Kubiena entitled *The Soils of Europe* (published in Britain in 1953, and reviewed in DISCOVERY in January 1954, p. 46) was notable for the excellent set of colour pictures it contained showing the profiles of some forty common soils. These coloured pictures have now become available as a separate publication entitled *Atlas of Soil Profiles*, published by Thomas Murby & Co. at 20*s*. Each picture is printed on a separate stiff sheet, and the loose sheets are contained in a serviceable folder.

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ASSISTANTS (SCIENTIFIC): The Civil Service Commissioners invite applications for pensionable posts.

Age at least 17½ and under 26 years of age on January 1, 1956, with extension for regular service in H.M. Forces, but candidates over 26 with specialised experience may be admitted.

Candidates must produce evidence of having reached a prescribed standard of education, particularly in a science or mathematical subject. At least two years' experience in the duties of the class gained by service in a Government Department or other civilian scientific establishment or in technical branches of the Forces essential in one of the following groups of scientific subjects:

(i) Engineering and physical sciences.
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Further particulars from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S.59/56. Completed applications should be returned as soon as possible, and in any case not later than December 31, 1956.

EXPERIMENTAL OFFICERS AND ASSISTANT EXPERIMENTAL OFFICERS in various Government Departments. The Civil Service Commissioners invite applications for pensionable posts. Applications may be accepted up to December 31, 1956, but forms should be returned as soon as possible as an earlier closing date may be announced either for the competition as a whole or in one or more subjects.

The posts are divided between following main groups and subjects (*a*) Mathematical and Physical Sciences, (*b*) Chemistry and Metallurgy, (*c*) Biological Sciences, (*d*) Engineering subjects and (*e*) Miscellaneous (including, e.g. Geology, Library and Technical Information Services). Two individual vacancies for Assistant Experimental Officers exist in the Nature Conservancy, one on recording changes in vegetation and the other on soil invertebrates.

Age limits: For Experimental Officers, at least 26 and under 31 on December 31, 1956; for Assistant Experimental Officers at least 18 and under 28 on December 31, 1956. Extension for regular service in H.M. Forces. Candidates aged 31 or over with specialised experience for Experimental Officer posts may be admitted.

Candidates must have at least one of a number of specified qualifications. Examples are Higher School Certificate, General Certificate of Education, Scottish Leaving Certificate, Scottish Universities Preliminary Examination, Northern Ireland Senior Certificate (all in appropriate subjects and at appropriate levels), Higher National Certificate, University degree. Candidates taking their examinations in 1956 may be admitted. Candidates without such qualifications may be admitted exceptionally on evidence of suitable experience. In general a higher standard of qualification will be looked for in the older candidates than in the younger ones.

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Further particulars from Civil Service Commission, Scientific Branch, 30 Old Burlington Street, London, W.1, quoting No. S94-95/56.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL, has a vacancy in the EXPERIMENTAL OFFICER CLASS in its Nuclear Physics Division, for an officer to help organise a small team working on the measurement of neutron spectra in reactors.

Applicants should be at least 26 years of age and possess minimum qualifications of Higher School Certificate in Science subjects, or equivalent qualifications. They should have a good general knowledge of physics with some idea of the basic concepts of nuclear physics. Several years' experience in a physics research laboratory, though not necessarily nuclear physics, is desirable. An aptitude for the design of small mechanical devices and an ability to improvise would be an advantage.

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INFORMATION OFFICERS required in London in the Public Relations Branch of the United Kingdom Atomic Energy Authority.

Applicants (preferably between 24 and 30 years of age) should either be scientists or engineers; or people already experienced in public relations, journalism, lecturing or exhibition work, who have some technical background. They should be able to write and/or speak well and interpret technical information to the general public. Successful applicants will work to public relations specialists and will be able to extend their knowledge of publicity techniques.

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The Nuffield Foundation, in pursuance of its programme for the advancement of sociological studies, is prepared to offer for the academic year 1956–7 a small number of scholarships and bursaries to enable graduates in academic subjects other than the social sciences, psychology or economics, to study the social sciences. The Foundation's particular object is to enable men or women, who are already well qualified in other disciplines, particularly the natural sciences or the humanities, to receive a training in, for example, political science, social psychology, anthropology, social statistics and sociology generally (but not economics) so that in due course they may undertake research or teaching in the United Kingdom in those subjects. *The scholarships*, which are the senior awards, are intended for persons who have already undertaken some post-graduate work in their own subject. *The bursaries* are intended to enable those who have recently graduated to take a course of training in sociological subjects. In the case of both scholars and bursars the Foundation will pay the cost of university and/or college fees in addition to a maintenance award. Graduates of Universities in the United Kingdom, of either sex and preferably between the ages of 22 and 35, are eligible to apply.

Applications for awards in 1956 must be received before May 1, 1956, by the Director, The Nuffield Foundation, Nuffield Lodge, Regent's Park, London, N.W.1, from whom full particulars and application forms can be obtained.

L. FARRER-BROWN,
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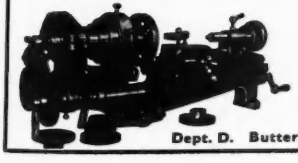

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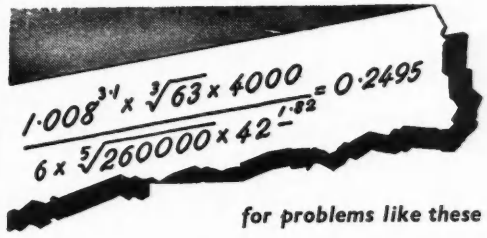

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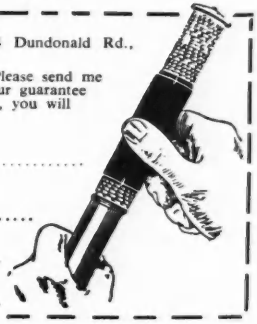

Strange as he might look arriving at Hatfield Station on an English summer day, the Eskimo would not have to travel far to feel at home. For almost within sight of the platform lies De Havilland's low-temperature test room. Here, gloved and helmeted against intense cold, research workers study the behaviour of aircraft parts under Arctic conditions. The large test chamber in which they work can be cooled to 135° of frost in less than an hour and a half — thanks to 'Drikold', the solid carbon dioxide or 'dry ice' refrigerant made by I.C.I. 'Drikold' is widely used, not only by British aircraft manufacturers and other industries that require coldness without fuss or mess, but also by those needing a convenient source of carbon dioxide gas. In the engineering, ice-cream, meat, fish, brewing, soft drink and many other industries, 'Drikold' plays its part in providing coldness, freshness, 'head' or 'fizz' all the year round.

The North Pole comes to Hatfield

Thus, and in a thousand kindred ways, I.C.I.'s research and production are serving the Nation.

ICI

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